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AUTHOR Vetter, Betty M.
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ABSTRACT

This report, which includes 51 tables and charts, examines past, present, and future imbalances in the supply of and demand for scientists and engineers. The supply is assessed by source and by field, and compared with current and short-range demand for new graduates and for experienced scientists and engineers, including assessment of the increasing participation of women and foreign nationals in degree output. Fields considered include: engineering; physics; geosciences; chemistry; mathematics, statistics, and computer science; life sciences; and social and behavioral sciences. Surveys projecting supply/demand imbalances (for college graduates, for scientists and engineers, for professional and technical workers, in the electronics industry, and in magnetic fusion energy) over the next decade are also examined and compared. Where differences of opinion exist about future supply and utilization, attempts are made to reconcile or explain those differences of opinion, or to supply additional assessment. One conclusion reported is that although the supply of most scientists (with the exception of computer scientists) appears to have caught up with, and generally exceeded the number of job opportunities in science, actual employment continues to be low among scientists relative to employment of other groups with similar amounts of education and training. (JN)

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STAFF

Betty M. Vetter - Executive Director
Eleanor L. Babco - Associate Director
Susan J. Fisher - Research Assistant

SUPPLY AND DEMAND

for

SCIENTISTS AND ENGINEERS

Second Edition

by

BETTY M. VETTER

Executive Director

SCIENTIFIC MANPOWER COMMISSION
1776 Massachusetts Avenue, N.W.
Washington, DC 20036

Telephone: (202) 223-6995 or (202) 467-4325

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FOREWARD

This report reviews available studies of the past, present and projected supply of scientists and engineers, and their utilization in science and engineering.

Where differences of opinion exist about future supply and utilization, this study attemps to reconcile or explain those differences of opinion, or to supply an additional assessment. While neither this author nor others whose studies are reported here can be certain of future balance or imbalance between supply and demand, readers may find it helpful to have various projections available in the same document for their consideration.

In addition to Endnotes and References to the text which start on page 41, the data sources utilized for Tables and Figures are listed beginning on page 43. The Bibliography on pages 46-49 is organized alphabetically by publisher.

Special thanks are extended to Sally Yochelson, Dean Vetter, and the staff of the Scientific Manpower Commission for their invaluable assistance.

Betty M. Vetter

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INTRODUCTION

Being able to assess whether supply and demand are or will be in fairly good balance over some period in the future is important to young people trying to plan their educations toward particular careers; to scientists and engineers already at work in the labor force who need to know where changes in balance are likely to occur; to colleges and universities and other training institutions; and to the employers of scientists and engineers. Although no perfect system for forecasting has been developed, available indicators provide useful information.

Who Needs Projections?

- Young people thinking about career goals want to know whether there are likely to be employment opportunities in science and engineering fields, and, in general, what areas of science or engineering are most likely to need significant numbers of new entrants. While no one would advise students to choose a career solely on the basis of its apparent job opportunities at any particular time, this information helps them to make informed decisions when added to such other factors as personal aptitudes and interests, opportunities for education, and the number of years they are willing to spend in preparation before moving into the world of work.

- Scientists and engineers who become aware that the field in which they are working is getting overcrowded may wish to examine peripheral fields in which opportunities may be better in the near future, and start preparing themselves to make a shift at the most advantageous time. Those who do not take advantage of opportunities to look ahead may be totally unprepared to face a job shift if one becomes necessary.

- Colleges and universities must plan ahead in developing faculty, estimating student demand for particular courses and curriculums, and developing counseling programs. Such planning is assisted by information about the current and projected job market. Forecasts of over- or under-supply are among factors used by training institutions in deciding whether to add or drop particular programs. In the mid-1970's, projections of over-supply at the doctorate level were cited among reasons for dropping doctorate programs at a number of state-supported schools.

- Employers of scientists and engineers including the colleges and universities that train them, need information about potential shortages or surpluses of scientists and engineers as a part of their long range planning. If a shortage of engineers appears to be developing, for example, an individual employer might wish to take steps to encourage those already in his employ to stay there; to see that opportunities for an engineering education are offered to young people in his community who might not otherwise be able to undertake such education; or that programs are begun to upgrade technical employees.

Although the kinds of information needed by each of these individuals or groups may be different in its level of sophistication, knowledge of the general trends is important for each of them.

How Projections Are Made

Assessing the future is difficult in any area, and particularly difficult when trying to anticipate how well the needs for particular kinds of training will match with the number of people trained in a period that must be at least four years and often eight to ten years ahead. There are a number of unknown factors in the equation needed to make such projections, and some assumption must be made for each of these unknowns.

Developing a model to predict whether supply and demand will be in balance at some period in the future requires making assumptions about what young people entering college may decide to study, and the basis on which that decision will be made; the level of funding that will be available from any and all sources to employ the scientists and engineers who will be seeking jobs; and how each of these will affect the other. At present, there are no perfect predictive models, or even any that consistently have worked well in the past.

Several kinds of models are used. One forecasting method projects what has happened in the past into the future. There are any number of variables that can be used within this kind of trend projection model, including heavier weighting of the most recent time period involved in the projection, or weighting for other factors such as an expected increase in the participation of women in areas where they have not previously been engaged in large enough numbers to be significant. The simplest trend models of supply use basic demographic information such as the number of young people who will reach age 18 or 22 in any year ahead; assume that the behavior of this group will be similar to the behavior of earlier cohorts in terms of the proportion that will choose to enter science and engineering, and thereby estimate the supply of new entrants over some particular period of time in the future. This number will be added to the present supply.

Using available demographic data from the past, such a model will then subtract appropriate numbers for each year for death and retirement, emigration, and transfers to other fields. Additions will be made for immigrant scientists and engineers and for transfers from other disciplines. The result will be an estimate of the number of persons who should be available and trained at any particular point in the future. This trend model can be adjusted by weighting any factor more heavily or by adding into the model a predicted effect for such changes as tuition increases, drops in federal funds for student grants and loans, increases in student populations by the introduction of re-entry women, or changes in student choices occasioned by differences in entering salary

levels or student perceptions of employment opportunities. Both the simple and the more complex trend models show a mixed record in predicting future supply. Trend models may give poor results if one or more factors reverse direction or even slow or speed the rate of change. For example, projections of degrees made ten, five, and even two years ago, failed to anticipate the rapidity of increase in the participation of women in science and engineering.

One way of projecting future demand is to ask a number of knowledgeable persons from major employing companies or institutions about their hiring plans; to combine and average or weight their responses and compile a statistical forecast. For example, a large number of industrial employers may be asked about their plans for hiring more scientists and engineers over certain periods of time in the future. Such respondents generally are asked to separate anticipated hiring to indicate how many will be hired as replacements for persons expected to leave and how many are expected to be net increases in the total number employed. The responses are then aggregated, producing an estimate of the number of scientists and engineers who are likely to be hired by all such employers if plans do not change. Of course, plans do change, and if the plans of a number of participants change in the same direction, the estimates will fail substantially to meet the reality.

Projections of demand sometimes are made by estimating a value for some factor such as the Gross National Product, and assuming that some proportion of the GNP can be translated into jobs for scientists and engineers. Research and Development budgets, correlated with cost per scientist or engineer, can be used to estimate demand for some activities.

Still other projections are based on an effort to predict how much funding will be applied to solve a particular problem such as protecting the environment, developing new weapons systems, or working toward energy independence. This kind of projection is not particularly useful in determining total manpower demand for scientists and engineers unless many other problem sectors also are projected at the same time and with the same set of basic assumptions. Therefore, such projections often are made under several different scenarios - which assume increased or reduced emphasis on one or more national endeavors.

How Projections Are Used

In every case, projections for the future require that some assumptions be made about both present and future factors that will affect the supply of or the demand for scientists and engineers. The projections themselves may affect the outcome. For example, when high demand is projected for a particular area, more students will enroll in programs that will prepare them for those jobs.

Right or wrong, such assessments, if widely publicized, can change supply, and therefore the balance between supply and demand, by influencing the actions of potential students, employers, and training institutions. Some of these influences are inadvertent, and some are intentional.

Projections may result in modification of the amount of support available to assist students obtain training in science and engineering, in order to increase or decrease the available manpower a few years later. Through the 1960's, since most projections indicated a shortage of trained people in almost all fields of science and engineering, support

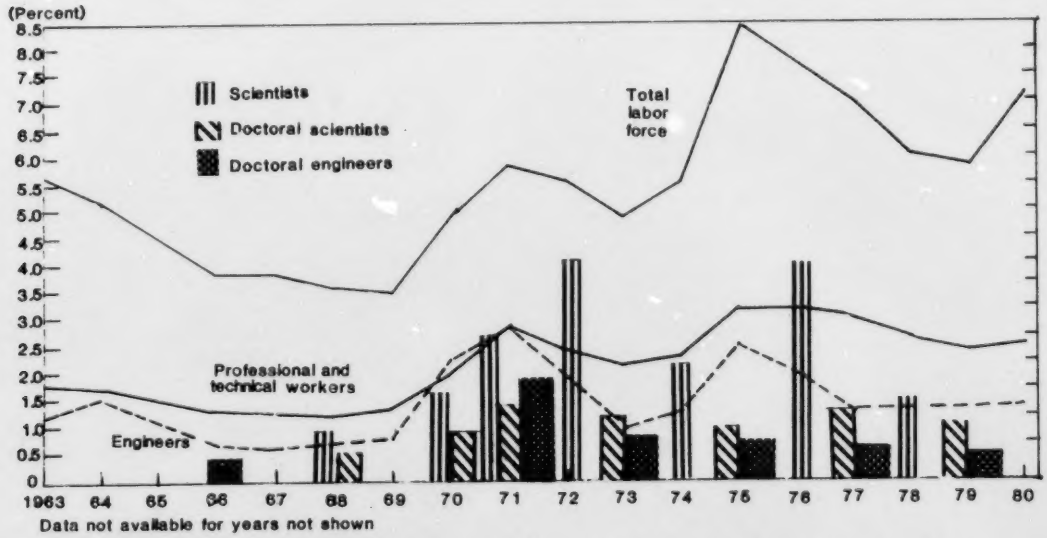

Figure 1. Unemployment Rates [Data Sources: Bureau of Labor Statistics and National Science Foundation]

for the training of scientists or engineers was increased. More recently, some of the effort has moved in the opposite direction. For example, a 1976 National Research Council report on the need for biomedical and behavioral scientists[1] indicated that some surplus of trained persons already existed and recommended that support for predoctoral training in some instances be reduced.

Even though the art of forecasting presently is inexact, and indeed sometimes grossly in error, forecasts are one of the necessary tools for planning. Such forecasts should be monitored and updated on a regular basis.

SUPPLY AND DEMAND IN THE SEVENTIES

Beginning during World War II, and continuing through the 1960's, rapid technological advancements and an increasing population resulted in the utilization of almost all the scientists and engineers available and the economy displayed a voracious appetite for more. There were chronic shortages of certain kinds of scientists and engineers through the middle fifties, and great efforts were made to increase the number of persons trained in those areas, both for traditional activities and for such special programs as space exploration. By the middle sixties, these efforts in the form of scholarships and fellowships and G.I. educational benefits, coupled with a rapid increase in the number of college-age students and in the proportion of this group entering higher education, had resulted in a substantial increase in the number of science and engineering graduates.

Unfortunately, these programs had been set in motion with the assumption that shortages would continue indefinitely, and no long range plans were formalized for assessing continued need for them. Thus, in 1967, when budgets for the space program hit their peak, young men (and an occasional woman) were still pouring into the educational pipeline to prepare for careers in aerospace engineering, and indeed in all fields of engineering. Even by 1969,

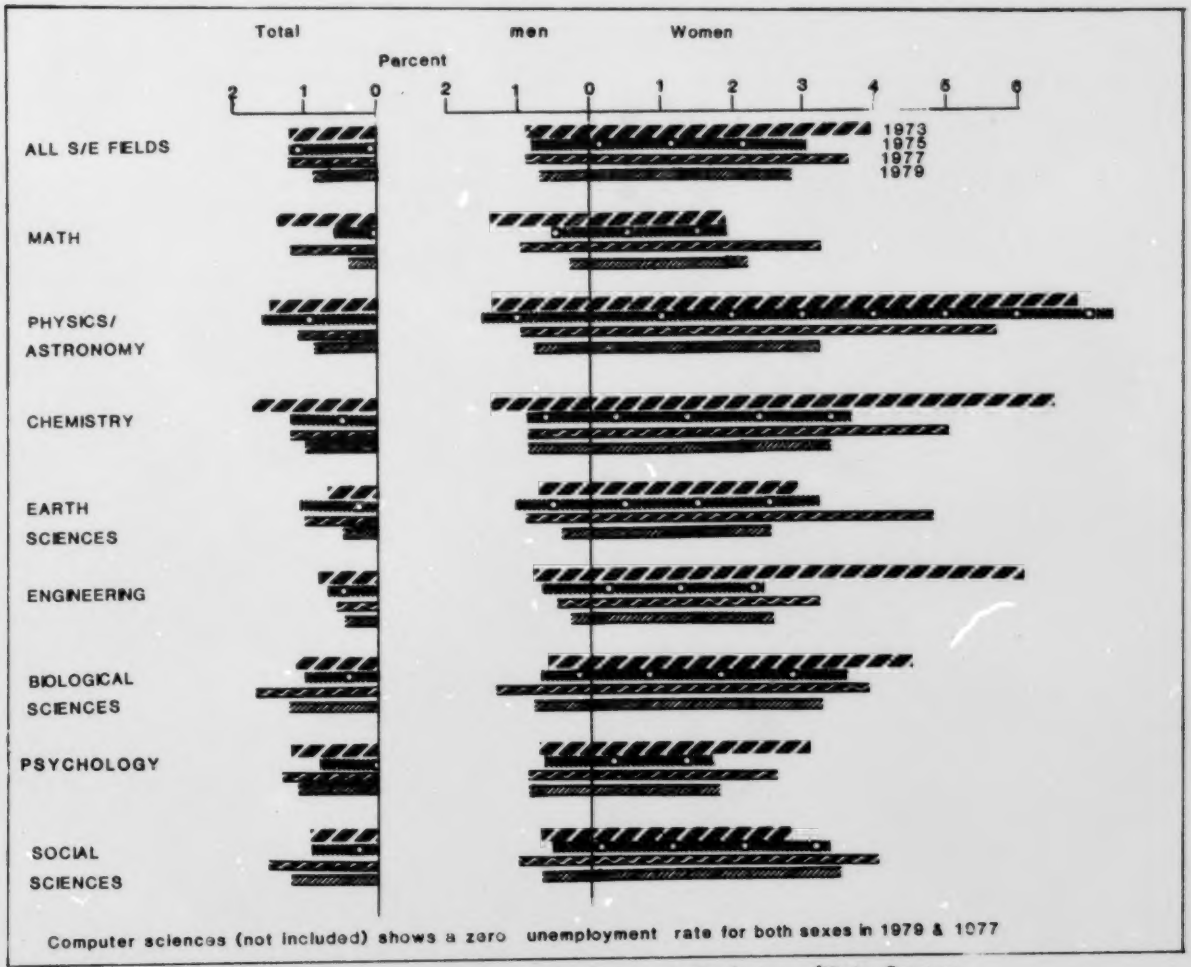

Figure 2. Unemployment Rates of Doctoral Scientists and Engineers [Data Source: National Research Council]

when budget figures for space and other programs were dropping steadily, freshmen engineering enrollments were still holding at about 75,000 entrants, although a small drop had occurred. This meant that the graduating classes of 1970 through 1973 hovered near 43,000 per year.

Unemployment For Scientists And Engineers

In addition to dropping budgets in the space program, the economy began to falter following years of inflationary guns-and-butter budgets. Industry as well as government not only reduced hiring substantially but also began large layoffs of engineers and scientists. By 1971, the unemployment rate for engineers and some scientists reached 3% (Fig. 1) even as record classes of new graduates at all degree levels poured out of colleges and universities to swell their ranks.

Following a drop in unemployment in 1973, the unemployment rates started up again in 1974 and peaked in 1975 for engineers and probably in 1976 for scientists.[2] Although the unemployment rates for engineers had been somewhat higher than for scientists in 1971, engineers have shown lower unemployment rates than scientists through the remainder of the decade. Both in 1972 and in 1976, the unemployment rate for scientists exceeded the rate for all professional and technical workers.

Over the decade of the seventies, both scientists and engineers became increasingly aware of the seriousness of oversupply problems, and the student population in most of the science fields has dropped consistently since 1972. On the other hand, freshmen engineering enrollments bottomed out in 1973, and have been rising steadily ever since in response to a good job market for graduates. The variation in supply/demand imbalances in the various fields of science and engineering indicate the need to examine these fields separately, and in as much fine field detail as available data allow.

Doctoral Scientists And Engineers

Unemployment rates among doctoral scientists and engineers have been measured in alternate years

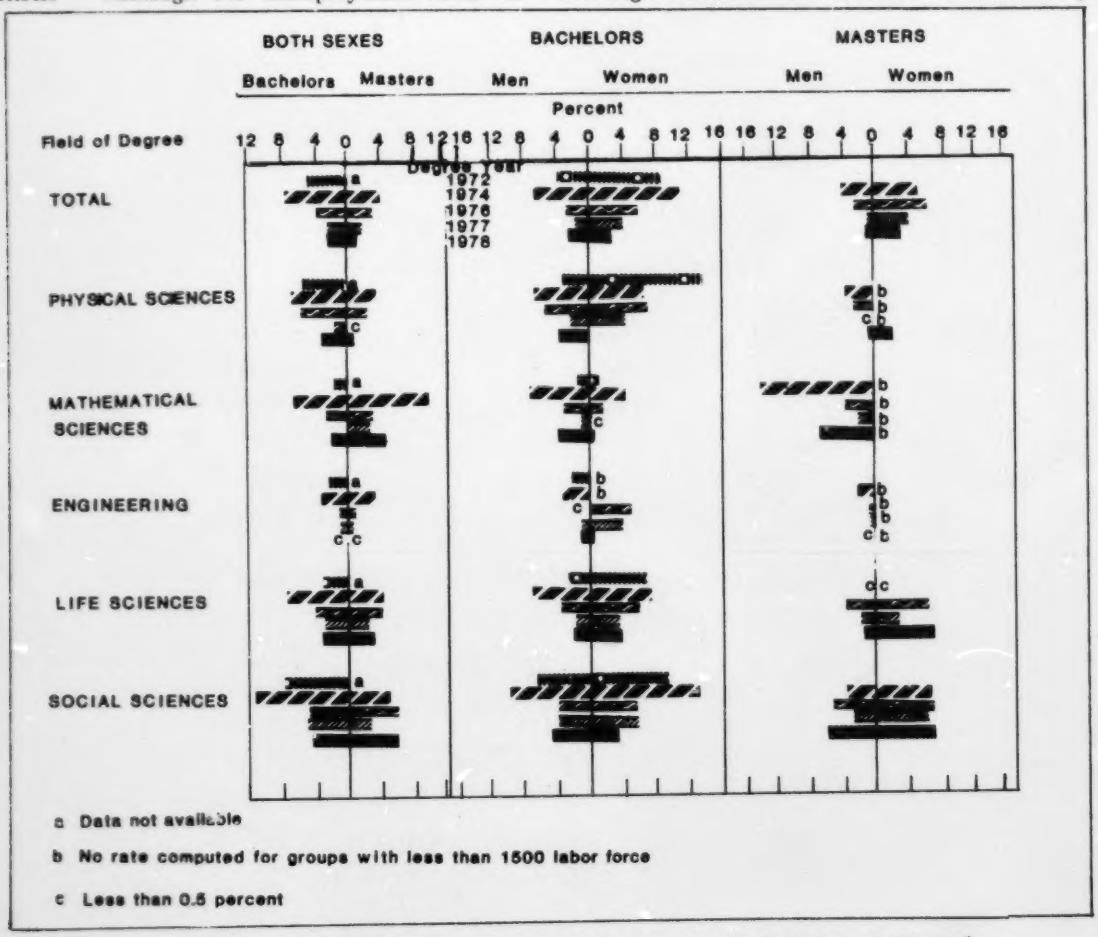

Figure 3. Unemployment Rates of Science and Engineering Bachelor's and Master's Graduates Two Years After Graduation, 1974, 1976, 1978 and 1980 [Data Source: National Science Foundation]

since 1973. The total unemployment rate has hovered near 1% through most of the decade, rising slightly to 1.2% in 1973 and 1977 (Fig. 2).

By field, physics and chemistry had the highest unemployment rates in 1973 and 1975, but the biological and social sciences had the highest rates in 1977 and 1979. The lowest unemployment rates have been in computer science, where no cases of unemployment were reported in either 1977 or 1979; in engineering; and in the earth sciences.

Unemployment rates for women have remained three to four times higher than for men in every field in every survey year. In part, this may reflect the higher proportion of younger graduates in the female doctoral population, since unemployment has been somewhat higher for more recent graduates than for those who have been in the labor force longer.

Recent Science And Engineering Graduates

One indicator of imbalance between supply and demand can be seen in the rate of science or engineering employment and of unemployment among recent bachelor's and master's graduates in these fields. While an educational background in science and engineering is excellent preparation for a wide variety of occupational endeavors, either an exceptionally high unemployment rate among recent graduates in these fields or an unusually low science and engineering utilization rate generally indicates an oversupply.

Unemployment rates among bachelor's and master's graduates surveyed since 1972 two years after receipt of the degree,[3] indicate that the highest unemployment rates occurred in 1976 when the 1974 graduates were surveyed. Almost 8% of the bachelor's graduates and 4% of the master's graduates were unemployed and seeking work two years after earning the degree (Fig. 3). The unemployment rates were highest among graduates in the social sciences, but all fields show the increased rate for the 1974 class. National unemployment peaked in 1975, and the rates may have been even higher in that year. The unemployment rates generally have dropped for each succeeding class surveyed through 1980.

Almost without exception, the unemployment rates for women have been higher than for the men with whom they graduated, and this has been true through each succeeding survey, although the gap in

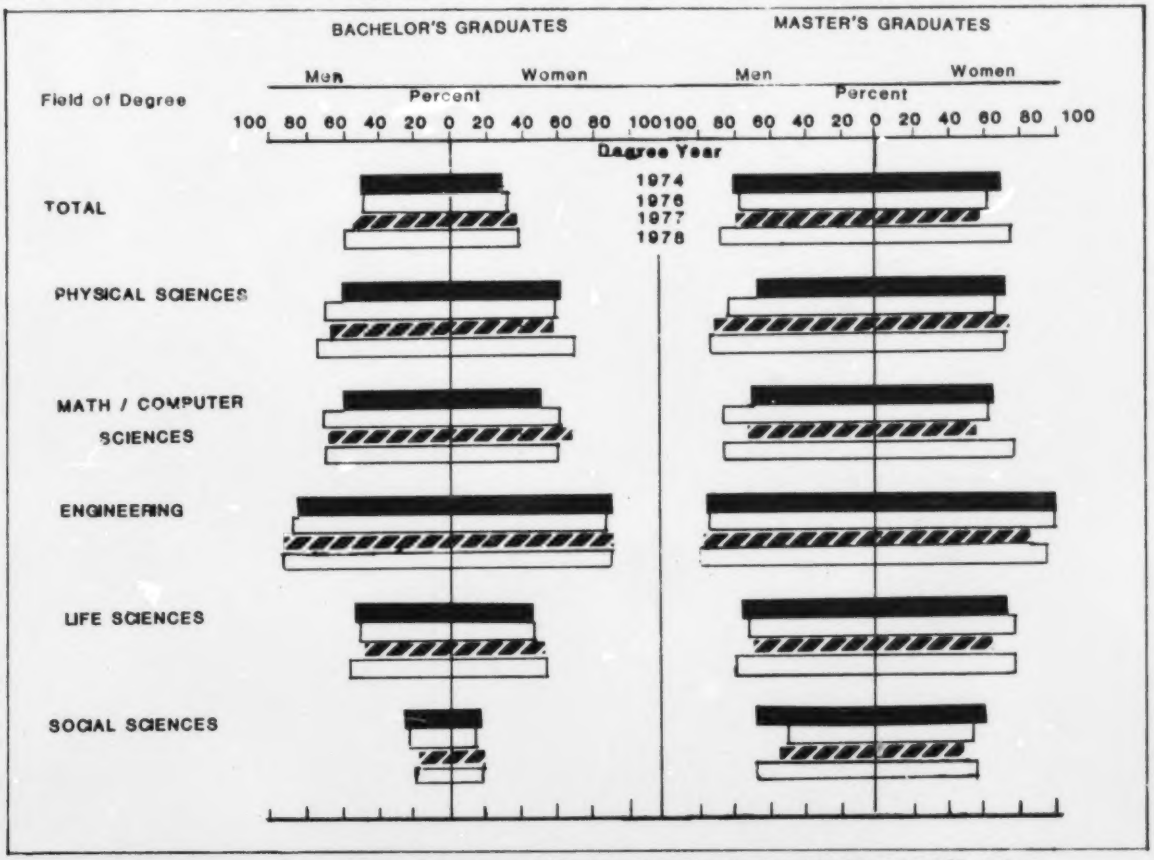

Figure 4. Percent of Employed Science and Engineering Graduates Working in S/E Jobs Two Years After Graduation, by Field and Level of Degree and Sex [Data Source: National Science Foundation]

the unemployment rates between recent men and women graduates continues to decrease. This apparent preference of employers for male graduates also can be seen by examining the proportion of the employed graduates in each field who found science and engineering employment (Fig. 4).

Bachelor-level engineers of both sexes are the most likely of all the science and engineering graduates to be employed in science and engineering jobs; and social and behavioral graduates the least likely to find S/E employment at the bachelor's level. While this may indicate an undersupply of engineering graduates and an oversupply of graduates in the social and behavioral sciences, it is also related to the typical entry level for these fields. A bachelor's degree is sufficient for professional employment in engineering or computer science, but a graduate degree is generally required for professional entry to the social or life sciences.

About half of the male and 30% of the female bachelor's graduates in science and engineering of the class of 1974 who were employed in 1976 were employed in science or engineering jobs. By 1980, when the 1978 and 1979 classes were surveyed, 58% of the men and 37% of the women who were working were in S/E jobs, verifying the increasingly good job market in science and engineering demonstrated by decreasing unemployment rates. Much of the difference between men and women can be attributed to their field of degree, but not all of it.

Among master's graduates, the proportion employed in science or engineering is higher for both sexes, (85% for men and 67% for women), but the difference between men and women shows even wider disparity, extending across all major fields.

SUPPLY

The science and engineering pool is made up of persons already trained and in the labor force with new additions and subtractions constantly occurring. Persons are lost from this pool by death, retirement, and transfer out of these professions. Persons are added in four ways: by the input of new graduates at all degree levels; the immigration of previously

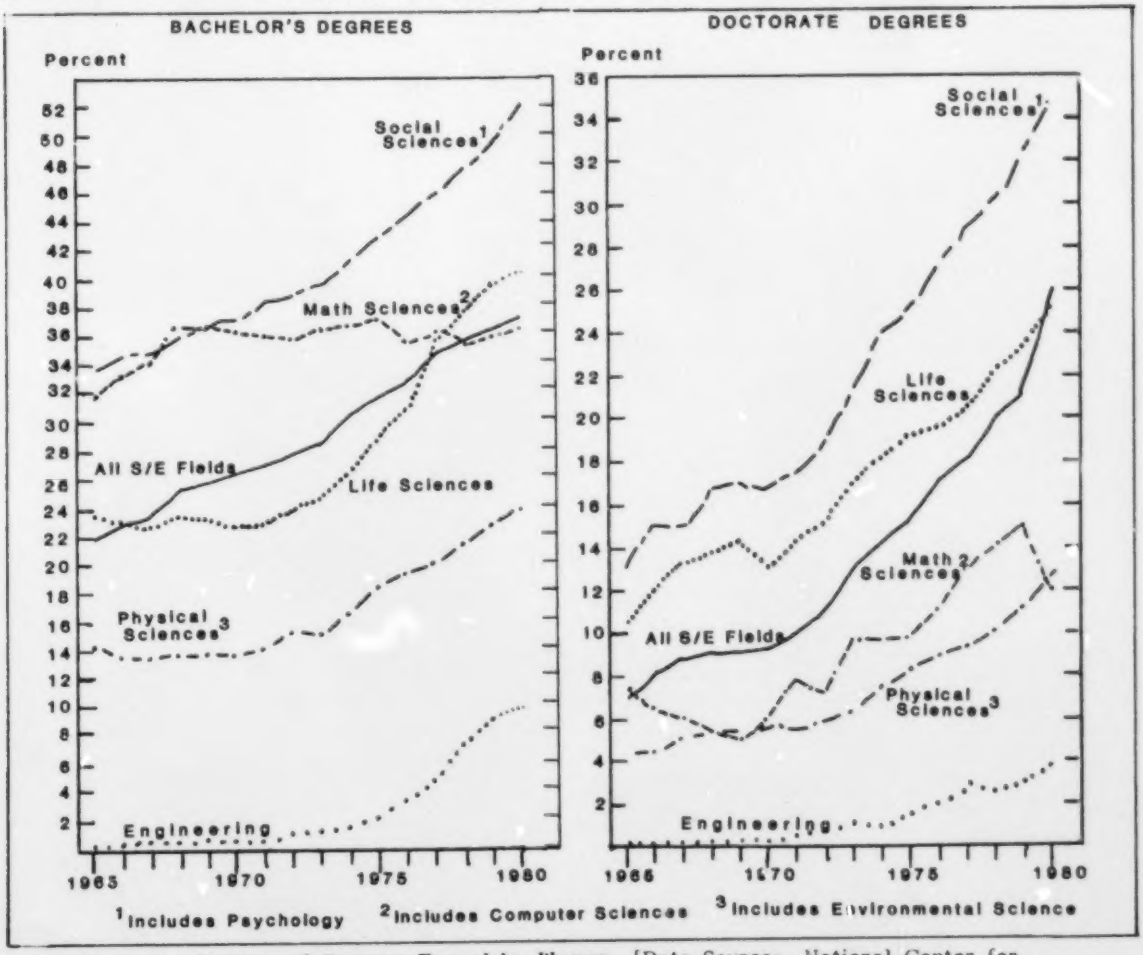

Figure 5. Percent of Degrees Earned by Women [Data Source: National Center for Education Statistics]

trained scientists and engineers from other countries; the transfer from other related disciplines; and by "upgrading." This latter process usually results from on-the-job experience, but sometimes it happens when qualified entrants cannot be recruited. Thus, the "upgraded" entrant, particularly in engineering where he is a major component of the engineering work force in some data, may be qualified only within narrow limits.

New Graduates

The most significant change that occurred in the seventies in the supply of new graduates was a change in the sex ratio of students earning science and engineering degrees. The total number of science and engineering bachelor's degrees awarded in 1980 was only 9.5% greater than the number in 1970, but the number awarded to women rose 55% while the number awarded to men dropped 6.5%. Women earned 26% of the science and engineering bachelor's degrees awarded in 1970, and 37% of those awarded in 1980 (Fig. 5).[4]

At the doctoral level, the change is even more startling. In 1980, the total number of science and engineering doctorates awarded was 2.5% higher than the number awarded in 1970, but the number earned by women was up 152% while the number awarded to men dropped 12.6%. Women earned 9.2% of all science and engineering doctorates in 1970 and 22.6% in 1980.[5] These increases in the number and proportion of women earning degrees occurred across all fields and at all degree levels (Fig. 5).

A second change in science and engineering degrees that occurred during the seventies is that the total number of degrees awarded in these fields dropped as a percent of all degrees awarded. In 1966, degrees in science and engineering were 33% of all bachelors degrees and 64% of all doctorates awarded. In 1980, they were only 30.8% of bachelors degrees and 58.7% of doctorates. These proportional changes by broad field are shown in Figure 6.

A remarkably consistent 30-34% of bachelor's graduates have majored in science or engineering over the past two decades, with internal field changes swinging the emphasis to and from the social sciences and the EMP (engineering, math and physical science) fields. In 1960, 17.3% of all bachelor's degrees were in EMP fields, dropping to 14.1% in 1965, 12.0% in

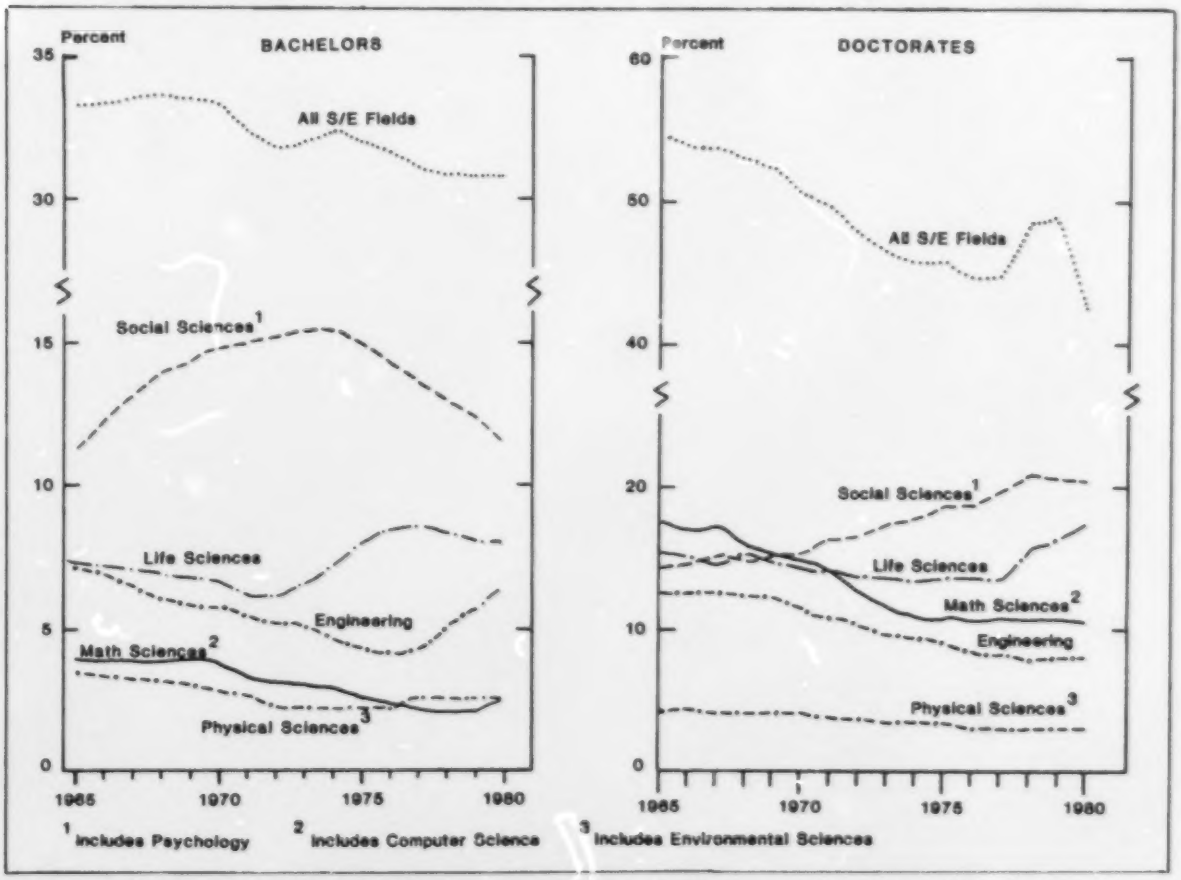

Figure 6. Science and Engineering Degrees as a Percent of All Degrees Awarded, 1965-1980
[Data Source: National Center for Education Statistics]

1970 and 9.1% in 1975. By 1980, that proportion is up to 11.2% because of the continued increases in engineering, and the drop in the social sciences.

However, the drop in S/E doctoral degrees since 1966 may be even more significant than it appears if we consider the increasing number and proportion of science and engineering degrees awarded at the doctorate level to foreign nationals on temporary visas. In 1966, in ten science and engineering fields where 88% of the S/E doctorates were awarded, 15.3% were awarded to foreign citizens on temporary visas. By 1980, those same fields accounted for 82% of all science and engineering doctorates, and 18.8% of the degrees were awarded to students on temporary visas (Table 1).[6] The shift is greatest in engineering, where the proportion of doctorate awards to foreign citizens on temporary visas increased from 16.7% of the total in 1966 to 37% in 1981. Other fields showing unusually high proportions of foreign recipients include agriculture and economics.

Table 1

PERCENT OF S/E DOCTORAL RECIPIENTS WHO WERE FOREIGN NATIONALS ON TEMPORARY VISAS, SELECTED YEARS

FIELD	1962 %	1966 %	1970 %	1974 %	1980 %
Physics/Astronomy	13.7	12.2	11.3	17.2	19.2
Chemistry	9.7	11.1	7.9	10.2	15.4
Earth/Env. Sci.	9.2	12.9	13.9	16.1	12.7
Mathematics	16.8	12.6	10.9	18.5	18.7
Economics	17.2	20.1	17.2	22.0	25.0
Political Science	19.1	13.0	9.3	10.8	11.9
Engineering	17.9	16.7	13.7	22.4	34.3
Biological Sci.	14.4	14.3	10.5	10.5	7.8
Medical Sci.	14.6	18.6	16.6	9.4	11.3
Agricultural Sci.	23.8	30.4	25.3	33.2	32.6
TOTAL	15.2	15.3	12.5	16.7	18.8

Data Source: National Research Council

In the 1980's, probably the most significant change that will affect the number of new graduates is the decrease in the size of the college age population. To some unknown extent, this drop may be compensated by an increase in the proportion of high school graduates of either sex who complete a college degree; by a continuing increase in the number of re-entry students, principally women, from earlier college-age cohorts; and (depending on the popularity of S/E majors among students) an increasing proportion of those degrees being awarded in S/E fields. The projections shown in Figure 7 assume that 71% of males and 76% of females from the average of the 17 and 18 year old population will graduate from high school through 1994. To project the potential number of S/E bachelor's graduates, the assumption is made that the number of male bachelor's degrees in science and engineering as a percent of male high school graduates four years earlier will increase from its low of 11.8% for the high school class of 1975 to 12.5% for the class of 1979, and will hold at that ratio through the next 15 years. For women, the 6.5% ratio for the high school class of 1975 is assumed to continue to increase by one-tenth of one percent each year to a total of 8.3% for the high school class of 1994.

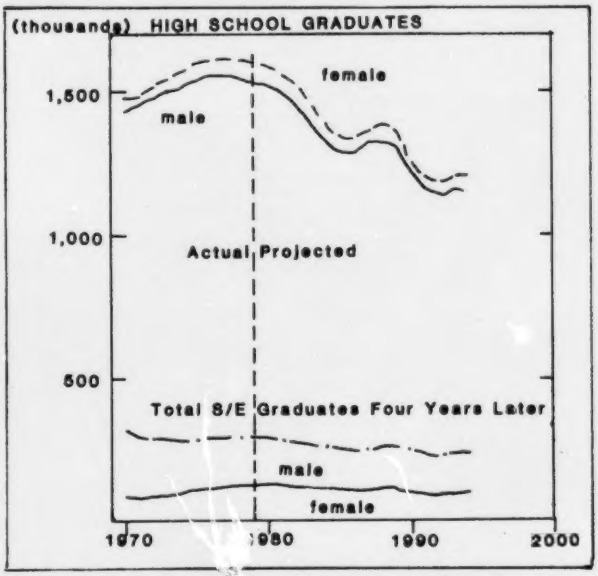

Figure 7. High School Graduates and S/E Bachelor's Graduates Four Years Later, 1970-1979 and Projected to 1994, by Sex [Data Sources: Bureau of Census, NCES and Scientific Manpower Commission]

If the job market in science and engineering, relative to the market in other degree fields as perceived by high school graduates of both sexes, remains good or gets better, the proportionate increases could be somewhat higher for both sexes. The percentage of male high school graduates of 1970 represented by S/E bachelor's degrees awarded to men four years later was 14.9%. On the other hand, if high school seniors perceive the job market in science or engineering to be poor relative to other degree fields or to opportunities for non-college graduates, the number of S/E degree awards could be substantially below the numbers projected in Figure 7.

The number of new graduates should be the least difficult segment of supply to project, at least over a short range of years, although both the extent and the rate of change in the sex ratio of degrees awarded has been underestimated by every national set of projections over the past decade.

In engineering, we can begin to count the number of degrees expected by examining enrollments in engineering at the freshmen year. In the sciences, where a graduate degree is more likely to represent the professional entrance level, some data are available on enrollments in the junior year. However, advanced degrees are more typically projected by utilizing the ratio of baccalaureate degrees to first year graduate enrollment trends, and relating this in turn to degree awards a few years later.

During the seventies, although increasing numbers of students entered and graduated from the nations institutions of higher education, including its graduate schools, the number of bachelors degrees awarded in science and engineering peaked in 1974 and the number of doctorates in 1973 (Figs. 8 and 9). Spurred by the rapid increase in engineering degrees since 1977, the total number of science and engineering bachelor's degrees started up again in 1979 and is expected to rise through 1982 before dropping again through the end of the decade.

Although the number of women earning doctorates more than doubled between 1969 and 1979, projections of degrees by the National Center for Education Statistics[7] assume that the number of doctorates earned by both men and women will rise in 1981 and then drop through the remainder of the decade. This may not be correct, since it appears quite unlikely that the increase in participation by women will stop while they still earn only one- fourth of S/E doctoral degrees.

The first test of the current projections of education statistics is a comparison of the actual number of doctorate recipients in 1980 with the number projected for that year by NCES in 1979, and published in 1980. As seen in Table 2, the total number of 1980 graduates projected was remarkably close to the actual number in most fields, although the total number of men receiving degrees was overestimated by 9.3% and the number of women underestimated by 2.5%. When only science and engineering doctorates are considered, however, the projected number for men is 0.9% higher than the actual number while the projection for women is 6.6% below the actual number. The total projection for science

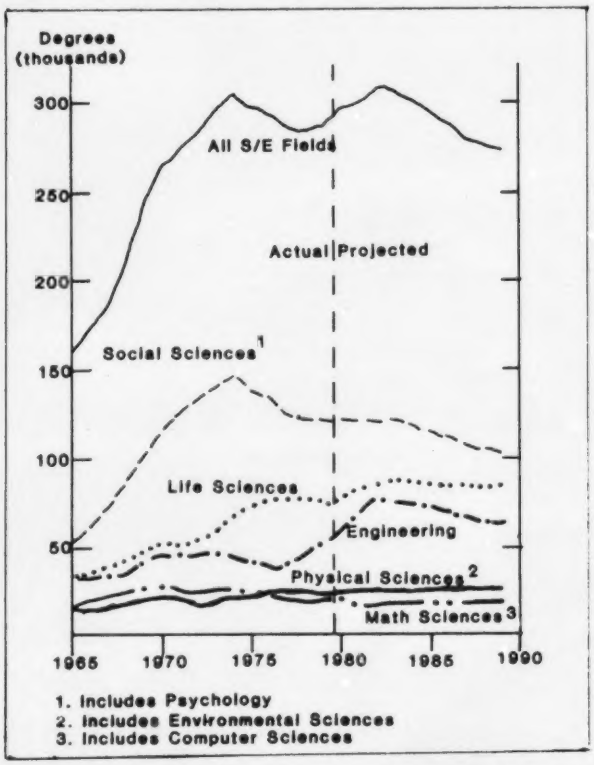

Figure 8. Science and Engineering Bachelor's Degrees, 1965-1980, Projected to 1989 [Data Source: National Center for Education Statistics]

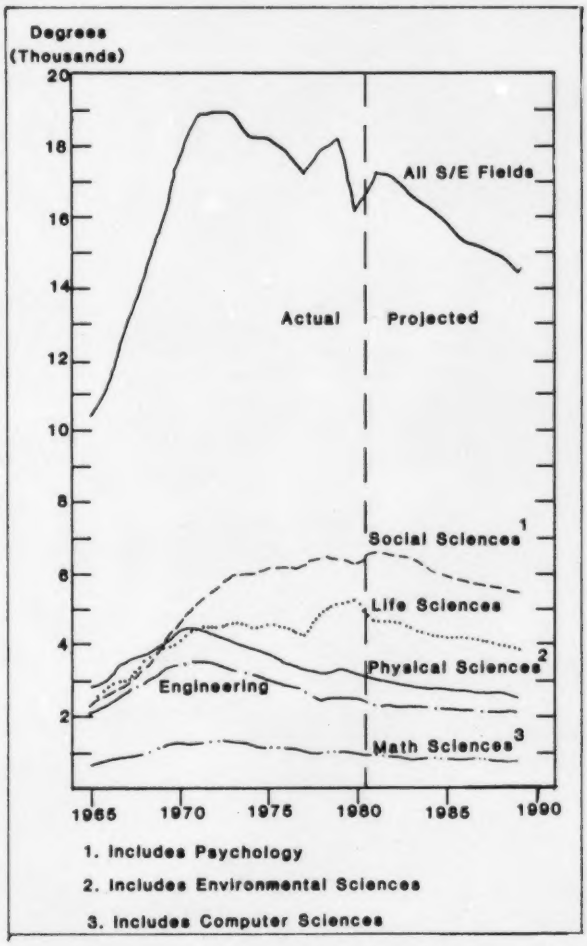

Figure 9. Science and Engineering Doctoral Degrees Awarded 1965-1980, Projected to 1989 [Data Sources: National Research Council and National Center for Education Statistics]

Table 2

1980 DOCTORATES, ACTUAL AND PROJECTED BY NCES

FIELD	Men		Women	
	Actual	Projected	Actual	Projected
Physical Sciences	2,765	2,760	386	330
Engineering	2,389	2,230	90	60
Mathematics/Statistics	650	630	95	130
Computer Sciences	197	180	21	20
Life Sciences	3,983	4,000	1,342	1,240
Social Sciences	2,300	2,800	855	980
Psychology	1,788	1,600	1,310	1,070
Total S/E Fields	**14,072**	**14,200**	**4,099**	**3,830**
Humanities	2,335	2,170	1,528	1,550
Education	4,201	4,490	3,375	3,120
All Fields	**21,595**	**23,600**	**9,387**	**9,150**

Source: National Center for Education Statistics and National Research Council

and engineering doctorates is only 0.8% below the actual figure for 1980, but the error in underestimating the number of women may continue to enlarge sufficiently to seriously understate the totals by 1989.

Because the supply of new graduates is not changing consistently within every field of science or engineering, it is helpful to look separately at several of these fields.

Engineering

In engineering, where we can get a measure of intended majors even at the freshman year, the enrollment drop from the fall of 1970 to the fall of 1973 was 29%. Freshmen enrollments leveled off in 1973 and started up again the following year to rise through the remainder of the decade. In part, this increase is made up of women who were 4.9% of the 1973 class and 14.5% of the fall 1980 freshmen. The number of men also increased, in response to excellent job prospects for graduates and high starting salaries. Overall, the freshmen class rose 121% from fall 1973 to fall 1980.[8]

When freshmen enrollment is plotted against first degrees[9] four years later (Fig. 10), we see not only the abrupt shifts in popularity of engineering among freshmen, but also a major change in the ratio of baccalaureate degrees to freshmen enrollments four and a half years earlier.

The freshmen class is reduced by attrition, especially after the freshman year, and augmented by input from two-year colleges (particularly at the junior level) and transfers from other subject areas. The continuing higher ratio of degrees to freshmen enrollment appears to be leveling off at around 70%, as the size of the junior class relative to the previous year's sophmore class continues to increase. If this pattern continues, the graduating class in 1984 should number about 76,000, with women constituting more than 14% of graduates (Table 3).

The National Center for Education Statistics (NCES) projects bachelor's degrees in engineering to 1989, and assumes that all graduating classes from 1982 onward will contain the same sex ratio—namely, 10.0% women.[7] However, comparing actual results now known for 1978-79 and 1979-80 and 1980-81[4] with the numbers projected by NCES in 1979,[7] we find that they overestimated the number of male bachelor's graduates in engineering in 1979 by 12.3%, while underestimating the number of women graduates by 10.3%. The total number of degrees was overestimated by 10.3%. In 1980, male graduates were overestimated by 10.7%; female graduates underestimated by 3.7%; with the total overestimated by 9.3%. In 1981, males are overestimated by 9.9%, females underestimated by 5.1%, and the total overestimated by 8.4%.

Bachelor's degree projections based on junior enrollments in engineering for 1982 and freshmen enrollments for 1983 and 1984[8] (Table 3) indicate a continuing rise in total degrees through at least 1984, but a smaller total than is projected by NCES for 1982 and 1983[7] (Table 4). The SMC projections of engineering degrees in Table 4 for the years 1985 to 1989 represent a percentage of the NCES intermediate estimates of total bachelor's degrees for men and for women. The estimates for 1990 to 1995

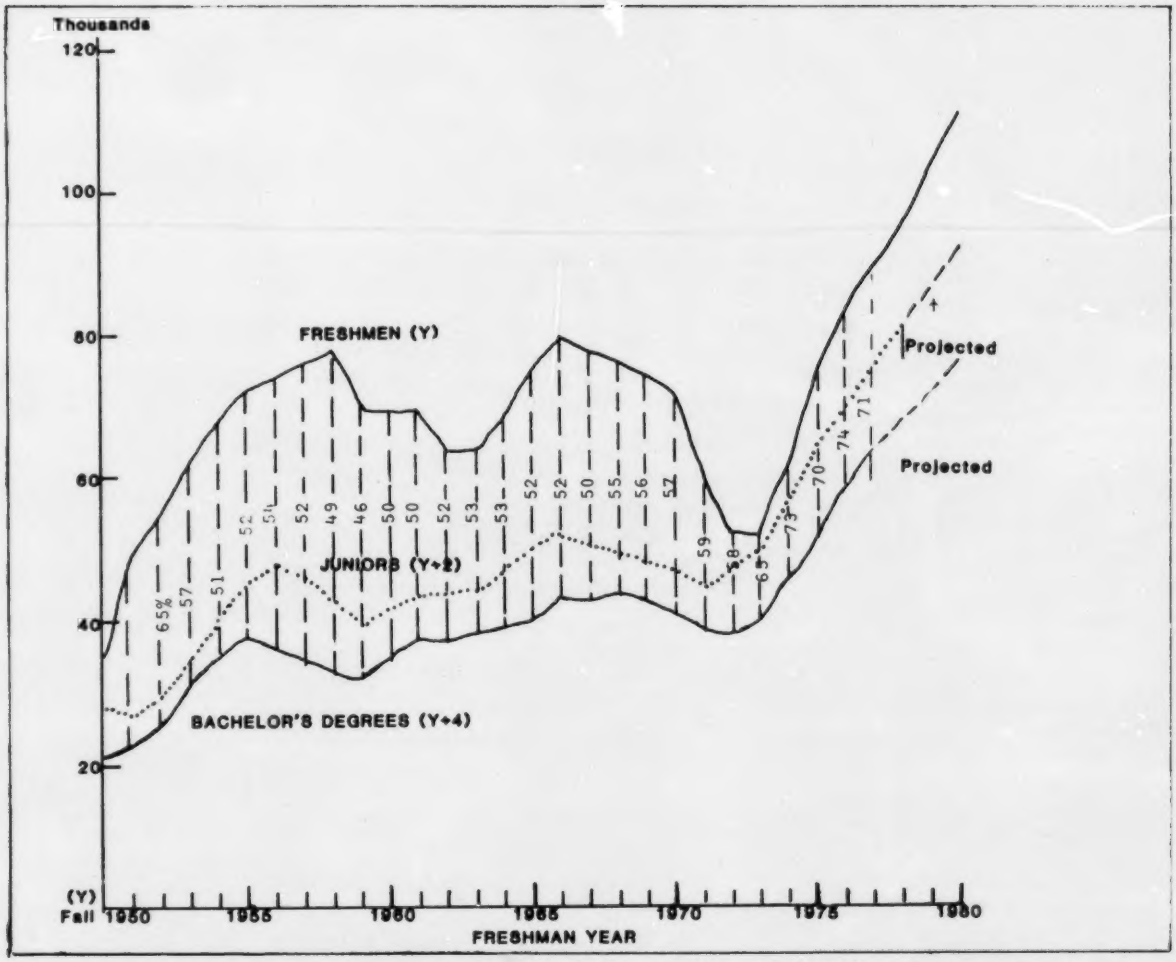

Figure 10. Freshman Enrollments, Junior Enrollments and B.S. Graduates in Engineering from Each Succeeding Freshman Class, and Ratio of Graduates to Freshmen Four Years Earlier [Data Source: Engineering Manpower Commission] (Projections by author)

included in Table 4 are based on the number of high school graduates four years earlier, and estimated at 4.5% of male and .75% of female graduates - proportions which match well with actual degrees awarded in earlier years and with projections derived by different methods.

However, these projections are believed to represent the numbers that could be expected based on two assumptions which, if not true, would drop the totals precipitously. First, they assume that demand for engineering graduates will continue to grow sufficiently so that almost all of the graduates who wish to enter engineering employment will find such employment, and that beginning salaries for engineering graduates will stay high relative to salaries offered to baccalaureate graduates in other fields. Second, the projections assume that schools of engineering will not cut back on the admission of qualified applicants, either as freshmen or transfer students, because of inadequate facilities and/or growing faculty shortages.

The shortage of faculty already threatens cutbacks at many engineering schools, particularly in the admission of transfer students at the junior year. Total undergraduate enrollment in engineering probably peaked in 1980 or 1981, so that the number of graduates will peak in 1984 or 1985. This would be expected to happen whether schools cut back on admissions or not. However, those classes may not be as large as is now anticipated if junior year transfers are limited in 1982 and 1983.

If those large classes (or subsequent classes) find difficulty in obtaining employment, both freshmen enrollments and transfer applications will drop off the following fall, as students seek other opportunities.

Added to the engineering graduates at the baccalaureate level will be graduates in engineering and industrial technology. Such four-year graduates now number about 10,000 per year,[9] and are expected to remain between 10,000 and 12,000 through 1989[7]

Table 3

BACHELOR'S DEGREES IN ENGINEERING AS A RATIO OF FRESHMAN ENROLLMENT FOUR YEARS EARLIER

Freshman Class Year Fall	Bachelor's Degree Year	Men			Women		
		Freshmen	B.S. Degrees	Ratio	Freshmen	B.S. Degrees	Ratio
1969	1973	72,932	42,805	58.7	1,181	624	52.8
1970	1974	70,204	40,663	57.9	1,457	744	51.1
1971	1975	57,025	37,332	65.5	1,541	878	57.0
1972	1976	50,558	36,594	72.4	1,542	1,376	89.2
1973	1977	49,512	38,134	77.0	2,417	1,961	81.1
1974	1978	59,178	42,815	72.4	4,266	3,280	76.9
1975	1979	68,613	47,873	69.8	6,730	4,716	70.1
1976	1980	73,705	53,062	72.0	8,545	5,680	66.5
1977	1981	78,859	56,390	71.5	9,921	6,557	66.1
1978	1982	87,016	57,548*	66.1	11,789	7,825**	66.4
1979	1983	89,693	62,068†	69.2§	14,031	9,513†	67.8§
1980	1984	94,145	65,148†	69.2§	16,004	10,851†	67.8§

* Estimated at 82.5% of Jr. Year Enrollments. ** Estimated at 76.2% of Jr. Year Enrollments.
§ Average of most recent 4 years. † Estimated ratio times Freshman Enrollment.

Data Source: Engineering Manpower Commission Estimates by Author

(Table 5). Women also are increasing their proportion in this population - from 1.3% in 1973 to 6.0% in 1981, and can be expected to hold or increase this representation at least over the next four years. They made up 2.8% of freshmen enrollments in bachelor of technology programs in 1973 and 9.9% in 1980. Their share of total full-time undergraduate enrollment has climbed from 2.3% in 1973 to 8.4% in 1980.[8]

The NCES projections[7] shown in Table 5 do not take this growth rate into consideration, and the degree proportions in these fields were underestimated at the bachelor's level by 23.1% for women in 1979, 85% in 1980 and 55.4% in 1981. Total engineering technology degrees at the bachelor's level were overestimated by 2.7% in 1979 and underestimated by 10.2% in 1980 and 13.3% in 1981. Although the total number of women earning these bachelor's degrees may not reach 1,000 per year, it will certainly be at least twice the number anticipated by NCES throughout the remainder of the decade.

If demand for engineering bachelor's graduates does not keep pace with the increasing size of the graduating classes over the first half of the eighties, some needed increase may occur in graduate enrollments. Typically, following a year when more baccalaureate graduates than usual are unable to find immediate employment, freshmen enrollments drop and first-year graduate enrollments rise, as in 1972.[8] When employment prospects at the bachelor's level are excellent, freshmen enrollment rises and graduate enrollment in engineering drops, as in 1976. As engineering employment opportunities increased through the second half of the seventies, the number of U.S. students going on to complete a Ph.D. has continued to drop.

Some of the drop has been filled by increasing numbers of foreign students (Table 1), some of whom will later become U.S. citizens, but most of whom are on temporary visas. The number of graduate degrees in engineering has been falling through most of the decade, and the number of foreign students in the degree population has been rising, so that foreign students on temporary visas now earn more than one-fourth of the master's degrees and one-third of the doctoral degrees awarded by U.S. universities[9] (Table 6).

In fall 1981, the faculty shortage of approximately 2,500 persons[10] is greater than the entire doctoral class in the previous year; and only 23% of the 1980 graduates indicated plans for employment in educational institutions.[6] Thus, the current faculty shortage will not be readily eliminated. Even among doctoral graduates who are not on temporary visas, many are not U.S. citizens. The National Research Council's 1980 report on doctorate recipients found that among engineering Ph.D.'s of that year, 46.3% are not U.S. citizens, although only 34.3% were on temporary visas.[6] Thus, even among those graduates who will remain in the U.S. after completing the

Table 4

ENGINEERING BACHELOR'S DEGREES, BY SEX, 1969-81 AND PROJECTED TO 1998

Year	Total	Men	Women	Projections by NCES		
				Total	Men	Women
1969	39,972	39,644	328			
1970	42,966	42,608	358			
1971	43,167	42,814	353			
1972	44,190	43,665	525			
1973	43,429	42,805	624			
1974	41,407	40,663	744			
1975	38,210	37,332	878			
1976	37,970	36,594	1,376			
1977	40,095	38,134	1,961			
1978	46,095	42,815	3,280			
1979	52,598	47,873	4,716	58,010	53,780	4,230
1980	58,742	53,062	5,680	64,200	58,730	5,470
1981	62,935	56,390	6,545	68,210	62,000	6,210
	Projected by SMC					
1982*	65,373	57,548	7,825	76,060	68,480	7,610
1983*	69,581	62,068	7,513	75,130	67,740	7,390
1984*	75,999	65,148	10,851	73,400	66,270	7,130
1985†	75,782	64,960	10,822	71,470	64,660	6,810
1986†	74,243	63,690	10,553	69,330	62,520	6,810
1987†	72,566	62,280	10,286	67,060	60,530	6,530
1988†	71,789	61,450	10,339	65,490	59,030	6,460
1989§	71,372	60,970	10,402	64,340	57,920	6,420
1990§	68,060	58,050	10,010			
1991§	69,322	59,130	10,192			
1992§	70,987	60,570	10,417			
1993§	68,820	58,725	10,095			
1994§	64,030	54,630	9,400			
1995§	61,250	52,200	9,050			
1996§	60,645	51,705	8,940			
1997§	61,500	52,425	9,075			
1998§	61,215	52,200	9,015			

* Based on present enrollments at Junior Year (1982) and Freshman Year (1983 and 1984).

† Based on NCES intermediate projections of total degrees at 13.3% for men, 2.4% for women.

§ Based on number of high school graduates 4 years earlier - 4.5% for men, 0.75% for women.

High school graduates estimated at 71% of males and 76% of females in averaged 17-18 year old population.

Source: Engineering Manpower Commission and Scientific Manpower Commission

Source: National Center for Education Statistics

doctorate, many may be less fluent in English than is desirable for teaching undergraduate engineering students.

The problem of insufficient faculty (which is experienced in the computer sciences as well)[12] may result in a significant reduction in the number of bachelor's degree awards projected over the remainder of this decade, and perhaps into the next. Projections of graduate degrees in engineering by the NCES (Table 6) indicade a continuing drop in doctorates through the eighties.

The faculty shortage has developed because industry has recruited most of the graduates at the bachelor's level, leaving relatively few to go on to graduate school and prepare for teaching. Additionally, engineers already on university faculties have been lured away by higher salaries and better equipment for research in industry, and by increased teaching loads and fewer graduate assistants in academe. During 1979-80, almost 400 full-time engineering faculty (2.7% of all permanent engi-

Table 5

BACHELOR'S DEGREES IN ENGINEERING AND INDUSTRIAL TECHNOLOGY PROJECTED TO 1989

Year	Total	Women
1973	6,478	70
1974	6,443	40
1975	7,909	85
1976	7,079	48
1977	7,682	193
1978	9,366	311
1979	8,714	366
1980	10,048	537
1981	11,657	718
	Projected*	
1982	10,550	350
1983	10,910	360
1984	11,160	380
1985	11,330	390
1986	11,480	420
1987	11,560	420
1988	11,730	430
1989	11,970	460

* Projections by NCES to 1989

Sources: Engineering Manpower Commission and National Center for Education Statistics

neering faculty) voluntarily left academia for full-time employment in industry.[10] In some cases, the salaries of doctoral engineers in private industry are nearly double those of engineering professors.

The shortage of engineering professors is expected to get worse and the quality of instruction to continue to degrade. As stated by Daniel C. Drucker, President of the American Society for Engineering Education and Dean of Engineering at the University of Illinois at Urbana-Champaign, the problem is not just that two few engineers are going on to graduate school, but that far too many of the best graduates are not going on.

A number of steps are now being taken to address this problem, but they may be both too little and too late to avoid a negative effect on both the quantity and quality of graduates in this decade.

Table 6

GRADUATE DEGREES IN ENGINEERING

	MASTER'S			PH.D'S		
Year	Total	Foreign Nationals	% F.N.	Total	Foreign Nationals	% F.N.
1969	14,980	1,784	11.9	3,387	410	12.1
1971	16,383	2,952	18.0	3,640	741	20.4
1972	17,356	2,973	17.1	3,774	773	20.5
1973	17,152	2,551	14.9	3,587	708	19.7
1974	15,885	3,009	19.5	3,362	1,014	30.2
1975	15,773	3,250	20.6	3,039	891	29.3
1976	16,506	3,691	22.4	2,977	1,060	35.6
1977	16,551	3,825	23.1	2,814	995	35.4
1978	16,182	3,720	23.0	2,573	874	34.0
1979	15,624	3,944	25.2	2,815	929	33.0
1980	17,243	4,512	26.2	2,751	982	35.7
1981	17,914	4,589	25.6	2,841	1,054	37.1
			Projected			
1982	16,340			2,330		
1983	16,440			2,270		
1984	16,310			2,230		
1985	16,310			2,170		
1986	16,200			2,130		
1987	16,200			2,090		
1988	16,060			2,050		
1989	15,930			2,000		

Data Sources: Degrees to 1981 - Engineering Manpower Commission
Projections to 1989 - National Center for Education Statistics

Table 7

PHYSICS ENROLLMENTS AND DEGREES AWARDED BY ACADEMIC YEAR 1969-81

Academic Year	Undergraduate Physics-Major Enrollment		Graduate Physics-Student Enrollment		No. of Physics Degrees Granted (July 1 to June 30)		
	Juniors	Seniors	Total	1st Yr.*	Bachelor's	Master's	Doctorate
1969-70	7,480	6,700	14,372	3,918	5,782	2,268	1,545
1970-71	6,884	6,663	14,327	3,494	5,755	2,300	1,530
1971-72	6,593	6,162	13,276	3,336	5,282	2,143	1,438
1972-73	6,012	5,806	11,804	2,904	4,923	1,961	1,445
1973-74	5,858	5,108†	11,119	2,680	4,852	1,772	1,236
1974-75	5,660	4,909†	10,410	2,668	4,571	1,650	1,167
1975-76	5,888	4,922†	10,372	2,646	4,487	1,570	1,111
1976-77	5,711	4,930†	9,991	2,624	4,517	1,469	1,051
1977-78	5,820	4,975††	9,835	2,499	4,457	1,422	971
1978-79	5,835	4,964	9,813	2,458	4,416	1,428	1,033
1979-80	5,696	4,942	9,647	2,439	4,440	1,370	912
1980-81	5,905	5,091	9,934	2,564			

* Includes part-time students who might be at the 1st-year level for more than one year.
† This total has been adjusted by 500 for students who are seniors for more than one year.
†† This total has been adjusted by 300 students who are seniors for more than one year.

Source: American Institute of Physics

Physics

In physics, undergraduate enrollment peaked in 1969 and dropped steadily through the seventies. This drop in enrollment reduced demand for physics faculty, and a significant fraction of new physics Ph.D.'s found placement difficult over the decade.[12] A recent study of postdoctoral appointments found that 48% of physics' postdoctorates were holding these positions more than two years, and 36% said that the prolongation was because no other positions were available.[13] The drop in supply appears to be reaching its end, as job opportunities have gotten closer in balance with the number of new graduates (Table 7).

While the number of women entering physics has been increasing, they have not yet affected total supply significantly. Women earned 13% of the bachelor's, 9% of the master's and 8% of the doctoral degrees in 1980.[4]

Geosciences

In the geosciences, where demand has been increasing with the search for new energy sources, bachelor's degrees have risen throughout the decade[15] (Table 8). Much of the increase is made up of women. The number of male bachelor's graduates rose 67% from 1971 to 1980, while the number of women increased 333%, for a total increase of 97.6%.

Table 8

GEOSCIENCE DEGREES

Year	BACHELOR'S			MASTER'S			PH.D'S		
	Total	Women	% W	Total	Women	% W	Total	Women	% W
1971	3,330	379	11.4	1,084	113	10.4	550	15	2.7
1972	3,861	489	12.7	1,299	150	11.5	580	21	3.6
1973	4,273	544	12.7	1,416	183	12.9	577	22	3.8
1974	4,834	800	16.5	1,604	201	12.5	570	29	5.1
1975	4,830	839	17.4	1,512	198	13.5	556	22	4.0
1976	4,864	916	18.8	1,515	218	14.4	584	53	9.1
1977	5,521	1,192	21.6	1,619	228	14.1	638	52	8.1
1978	5,885	1,318	22.4	1,760	295	16.8	623	61	9.8
1979	6,078	1,428	23.5	1,772	326	18.4	646	58	9.0
1980	6,214	1,513	24.3	1,740	336	19.3	628	64	10.2

Data Sources: National Center for Education Statistics and National Research Council

Table 9

ENROLLMENTS AND DEGREES IN GEOLOGY

Year	ENROLLMENTS				DEGREES		
	Junior	Senior	Master's	Doctorate	Bachelor's	Master's	Doctorate
Total							
1976	4,305	4,130	2,876	912	3,259	935	280
1977	5,825	5,699	3,457	1,125	3,740	920	257
1978	5,857	6,210	3,815	1,034	4,189	1,126	228
1979	6,131	6,880	3,968	1,075	4,334	1,204	222
1980	6,842	7,261	4,548	1,251	5,092	1,218	258
1981	7,511	8,424	4,883	1,257			
Percent Women							
1976	21.3	19.2	17.8	10.9	18.1	13.3	7.5
1977	22.4	20.1	18.5	15.9	21.5	11.8	7.8
1978	22.4	21.2	19.0	14.8	22.2	18.1	10.5
1979	24.5	23.9	20.5	18.0	23.7	18.9	9.5
1980	25.1	24.3	22.3	19.0	25.0	20.4	12.0
1981	24.2	24.4	23.8	19.5			

Source: American Geological Institute.

Master's degrees, generally the preferred degree for professional entry level, have gone up 68.5% (50% for men and 226% for women) while doctorates rose 14% (5% for men and 326% for women) between 1971 to 1980. The increase in master's degrees is well below that in bachelor's degrees, indicating (as in engineering) the excellent job opportunities and starting salaries at the lower degree level.

Geology is the predominant field in the geosciences, and a comparison of geology enrollments with degrees indicates continuing increases in these degrees, at least over the next several years[15] (Table 9).

Table 10

CHEMISTRY DEGREES

Year	Bachelor's	Master's	Doctorate
1964-65	10,047	1,715	1,414
1965-66	9,735	1,839	1,571
1966-67	9,872	1,831	1,744
1967-68	10,847	2,014	1,757
1968-69	11,807	2,070	1,941
1969-70	11,617	2,146	2,208
1970-71	11,183	2,284	2,160
1971-72	10,721	2,259	1,971
1972-73	10,222	2,230	1,882
1973-74	10,517	2,138	1,828
1974-75	10,649	1,986	1,822
1975-76	11,107	1,796	1,623
1976-77	11,215	1,767	1,570
1977-78	11,474	1,892	1,545
1978-79	11,643	1,765	1,567
1979-80	11,446	1,733	1,538

Source: National Center for Education Statistics

Chemistry

In chemistry, bachelor's degrees dropped in 1972 and 1973 before starting slowly up again in 1974.[4] Even by 1980, however, the number is still below the 1969 level (Table 10). The number of master's degrees peaked in 1971 and has remained below 2,000 per year since 1975.[4] Doctorates also peaked at the beginning of the decade, and remain below 1,600 per year.[5]

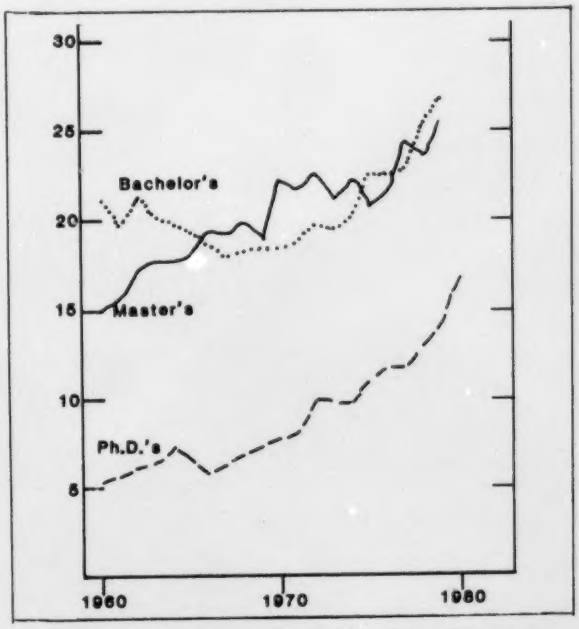

Figure 11. Percent of Chemistry Degrees Awarded to Women [Data Source: National Center for Education Statistics]

Women now earn about one-fourth of the bachelor's and master's degrees, and one-sixth of the doctorates - a continuing if not always steady proportional increase at all degree levels since 1960 (Fig. 11).

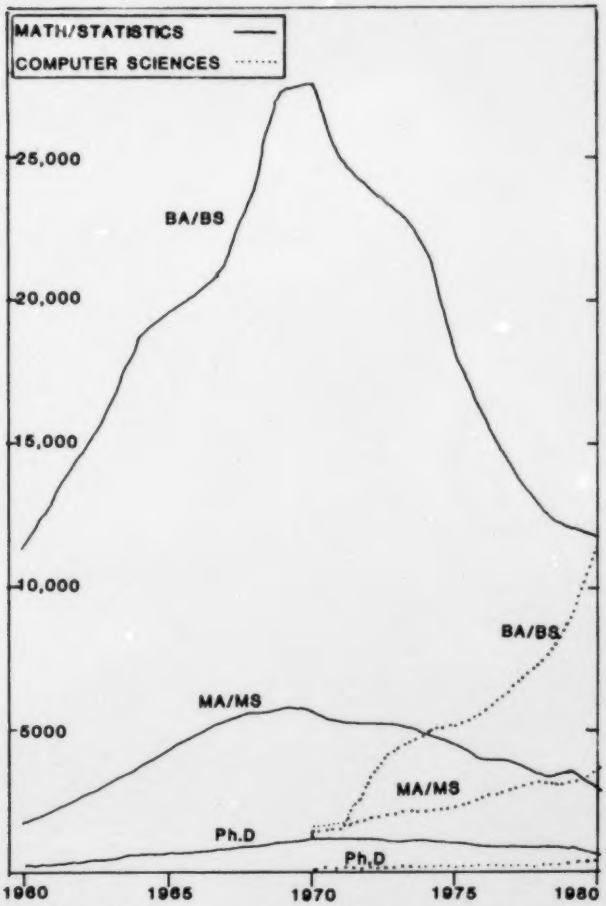

Figure 12. Degrees in Mathematics/Statistics and Computer Sciences [Data Source: National Center for Education Statistics]

Mathematics, Statistics and Computer Sciences

The number of degrees in mathematics and statistics has dropped so rapidly through the seventies that less than half as many bachelor's degrees were awarded in 1980 as in 1971 (Fig. 12). Some, but not all of the decrease, has been counterbalanced by an increasing number of graduates in computer science.[16]

Women have earned about two-fifths of the bachelor's, a third of the master's and one-tenth of the doctorates in mathematics and statistics through the seventies, but they are still below these proportions in computer science where job opportunities appear to be best.

NCES projections of degrees in these fields,[7] as shown in Table 11, indicates that a continuing drop is expected in mathematics and statistics degrees, with a continuing slow increase in computer sciences throughout the eighties for bachelor's and master's graduates. Again, NCES has seriously underestimated the number of women earning these degrees in the early years of the projections, and this error undoubtedly will grow larger through the decade. In 1980, NCES projected total computer science bachelor's degrees 29% below, men 8% below and women 51% below the actual number awarded. At the doctoral level, the total projection was 20% low with men 9% below and women 26% below the actual number. Similar underestimates occurred for math/statistics in 1980.

Computer science departments, like those in engineering, have serious faculty shortages, precipitated by the explosive growth in the computer field. The supply of new Ph.D.'s is only about 20% of the demand. The total number of Ph.D. graduates, the next generation of researchers and teachers, has decreased from 256 in 1975 to 248 in 1979 (Table 12). In 1979, there were 1,300 jobs advertised for these 248 Ph.D.'s, but fewer than 100 of them chose academic careers, and this group had more than 650 academic positions from which to choose.[12]

In 1980, among the 218 Ph.D's awarded in computer science, only 169 were awarded to U.S. citizens plus non-citizens with permanent visas, and only 40% of the class indicated plans for academic employment.[7] The total number of Ph.D. computer science faculty in the U.S. increased from 805 in 1975 to 837 in 1979. The net gain of 32 is 2.8% of the total 1,130 Ph.D.'s who graduated during that period. Most faculty outflux is into industry rather than retirement.

Undergraduate enrollments have doubled since 1975. Many students are attracted to computer science by its excellent career opportunities, and additional numbers of students are being encouraged by the computer revolution to take introductory and intermediate programming courses in order to be familiar with the computer as a tool in other disciplines. This has resulted in ballooning class sizes, inadequate terminal and computing facilities, insufficient laboratory facilities and an exodus of faculty to industry.

These shortages have put great pressure on salaries. In 1981, average starting salaries outside the academic sector were $20,700 at the B.S. level, $24,700 at the M.S. level and $30,900 at the doctoral level. By comparison, the median salary for assistant professors in engineering and computer science in 1980-81 was $21,500.[17] As in engineering, there is clearly little incentive for B.S. holders to contemplate graduate school when their current offers are comparable to those paid the newest faculty recruits.

Table 11

DEGREES IN MATHEMATICS/STATISTICS AND COMPUTER SCIENCES 1970-1980 PROJECTED TO 1989

	Bachelor's Degrees				Master's Degrees				Doctoral Degrees			
	Math & Statistics		Computer Science		Math & Statistics		Computer Science		Math & Statistics		Computer Science	
Year	Total	% W	Total	% W	Total	% W	Total	% W	Total	% W	Total	% W
1970	27,442	37.4	1,544	12.9	5,636	29.6	1,459	9.3	1,236	7.8	107	1.9
1971	24,801	38.0	1,624	14.5	5,191	29.2	1,588	10.3	1,199	7.8	128	2.3
1972	23,713	39.0	3,402	13.5	5,198	29.7	1,977	11.4	1,128	7.9	167	7.2
1973	23,067	40.2	4,305	14.9	5,028	29.9	2,113	10.6	1,068	9.6	196	7.7
1974	21,635	40.9	4,757	16.4	4,834	31.0	2,276	12.9	1,031	9.7	198	4.5
1975	18,181	41.8	5,039	18.9	4,327	32.9	2,299	14.7	975	11.3	213	6.6
1976	15,984	40.7	5,664	19.8	3,857	34.0	2,603	14.5	856	11.0	244	9.4
1977	14,196	41.5	6,407	23.9	3,695	35.2	2,798	16.7	823	13.2	216	8.8
1978	12,569	41.4	7,224	25.8	3,373	33.9	3,038	18.7	805	15.4	196	7.7
1979	12,115	41.6	8,769	28.1	3,578	33.8	3,055	18.8	933	16.0	209	12.9
1980	11,473	42.3	11,213	30.3	2,868	36.1	3,647	20.9	724	13.8	240	11.3
						Projected						
1981	8,120	38.4	8,730	25.4	2,540	37.0	3,580	22.9	700	17.1	190	10.5
1982	7,940	38.8	9,130	26.4	2,550	36.5	3,840	23.4	650	18.5	180	11.1
1983	7,960	39.2	9,660	25.4	2,550	36.1	4,050	23.7	630	17.5	180	11.1
1984	7,940	39.8	9,810	25.1	2,550	35.7	4,180	22.7	620	17.7	180	11.1
1985	7,900	40.4	9,830	26.9	2,560	35.2	4,340	21.7	610	18.0	170	11.8
1986	8,020	42.3	9,800	28.0	2,540	35.4	4,320	21.8	600	18.3	170	11.8
1987	8,000	43.3	9,780	28.7	2,530	35.6	4,280	21.7	580	17.2	170	11.8
1988	8,100	44.7	9,940	29.3	2,460	34.6	4,200	21.2	570	17.5	160	12.5
1989	8,180	45.7	10,110	29.0	2,420	34.3	4,140	21.0	550	16.4	160	12.5

Source: National Center for Education Statistics

This problem dips below the college level. In 1980, the membership of the Association of High School Science Teachers decreased by 10%; and most of the 1,000 teachers who left were hired by industry.[18] The fact that the United States is dependent on secondary school teachers to attract young people into scientific and technological careers compounds the problem of faculty shortage.

There is no excess of mathematics Ph.D.'s to be converted to computer science faculty. There was virtually full employment of Ph.D. recipients in mathematics from the 1979-80 class, according to the annual survey by the American Mathematical Society.[19] Additionally, there were virtually no unemployed ex-faculty members who had left academic life. The number of doctorate holding faculty members at four-year colleges and universities increased by about 400 in 1980, the largest increase in recent years, and compares to an increase of 275 in 1979. About 200 Ph.D.'s left academic positions for non-academic positions in addition to the 202 new doctorates who took non-academic positions in the United States. The number of non-doctorate faculty members in U.S. colleges and universities increased by a surprising 161 as compared to the 1979 decrease of 25, thus indicating no surplus of mathematics Ph.D.'s.

Table 12

U.S. COMPUTER SCIENCE PH.D. PRODUCTION AND FACULTY, 1973-80

Year	No. Ph.D's Granted in Computer Science	No. Faculty Holding Ph.D's	Total No. Faculty
1973	208	†	†
1974	203	787	862
1975	256	805	878
1976	246	773	843
1977	208	790	881
1978	214	825	938
1979	248	837	958
1980	265*	†	†

* Estimate † Not available

Source: Association for Computing Machinery, Communications, June 1981.

Enrollments in the mathematical sciences increased from fall 1979 to fall 1980 in courses in nearly every category, with the largest increases in computer science. Overall, graduate enrollment increased by 3.5%.[9]

Table 13

DEGREES IN AGRICULTURAL AND BIOLOGICAL SCIENCES 1970-1980 PROJECTED TO 1989

	Bachelor's Degrees				Master's Degrees				Doctoral Degrees			
	Agriculture/ Nat. Resources		Biological Sciences		Agriculture/ Nat. Resources		Biological Sciences		Agriculture/ Nat. Resources		Biological Sciences	
Year	Total	% W	Total	% W	Total	% W	Total	% W	Total	% W	Total	% W
1970	12,382	4.1	37,031	28.0	2,197	6.3	5,800	31.5	1,004	2.8	3,289	14.3
1971	12,672	4.2	35,743	29.1	2,457	5.9	5,728	33.5	1,086	2.9	3,654	16.3
1972	13,516	5.5	37,293	29.4	2,680	7.1	6,101	33.0	971	2.7	3,653	17.0
1973	14,756	7.4	42,233	29.8	2,807	7.8	6,263	30.5	1,059	2.6	3,636	19.5
1974	16,253	9.7	48,340	31.2	2,928	9.8	6,552	30.5	930	3.5	3,439	20.3
1975	17,528	14.1	51,741	33.1	3,067	11.9	6,550	30.0	991	3.3	3,384	22.0
1976	19,402	18.3	54,275	34.6	3,340	14.3	6,582	31.7	928	6.6	3,392	21.5
1977	21,467	22.3	53,605	36.2	3,724	14.7	7,114	33.7	893	6.9	3,397	21.4
1978	22,650	24.6	51,502	38.4	4,023	18.8	6,806	35.4	971	6.4	3,309	24.1
1979	23,247	27.1	49,576	40.6	4,007	20.2	6,879	37.7	950	7.7	3,548	25.6
1980	22,903	29.6	47,111	42.4	3,987	22.4	6,536	37.1	991	11.3	3,638	26.0
					Projected							
1981	25,740	26.4	55,890	38.7	4,370	24.9	6,880	41.0	1,100	6.3	3,510	25.1
1982	26,430	26.3	57,480	39.8	4,570	25.2	7,020	41.0	1,120	6.3	3,480	24.4
1983	27,080	26.6	57,570	39.8	4,760	25.8	7,120	41.6	1,110	6.3	3,350	24.8
1984	27,550	27.2	57,080	39.9	4,850	24.9	7,160	42.2	1,100	6.4	3,250	25.2
1985	27,800	27.6	56,140	40.1	4,990	24.2	7,170	42.0	1,080	6.5	3,140	25.5
1986	27,920	28.0	55,980	39.7	5,050	24.0	7,090	42.2	1,080	6.5	3,040	26.0
1987	28,000	28.4	54,910	41.9	5,100	23.3	6,990	42.5	1,070	6.5	2,950	26.4
1988	28,070	28.3	54,870	42.9	5,100	22.4	6,760	42.0	1,070	7.5	2,850	26.7
1989	28,550	28.8	55,030	43.5	5,120	21.7	6,570	42.2	1,060	7.5	2,760	27.2

Source: National Center for Education Statistics

Life Sciences

Degrees in the agricultural sciences increased through the decade at the bachelor's and master's level, and held steady at the doctoral level through the seventies[4, 5] (Table 13). However, about a third of the Ph.D.'s are awarded to foreign nationals on temporary visas.[6]

In the biological sciences, degree production increased until 1976 at the bachelor's and master's levels, and continues to show increases at the doctoral level through 1980[4, 5] (Table 13).

As in the social and behavioral sciences and in mathematics, women earn a large fraction of the bioscience degrees. Their proportion of degrees in the agricultural sciences remained well below 5% until the seventies, but has leaped to almost 30% by 1980 at the bachelor's level, 22% at the master's level and 11% at the doctoral level[20] (Table 13).

The projections of degrees in Table 13, as in Table 11, were made by the National Center for Education Statistics[7] before either the 1979 or 1980 degrees were available. In every instance, projections for 1979 and 1980 underestimated the proportion of degrees earned by women, and thus the projections from 1981 through 1989 in both tables may significantly understate the totals at the bachelor's level, with some underestimate at both graduate degree levels. If the number of male graduates is smaller than anticipated by NCES, the total projection may be near the mark.

The projected totals of bachelor's degrees in the biological and agricultural sciences are higher by 25% and 17% respectively in 1989 than in 1980. Master's degrees are expected to rise 28% at the master's level in the agricultural sciences, but to be essentially level in the biological sciences between 1980 and 1989. Doctoral degrees are expected to rise slightly in the agricultural sciences but to drop 24% in the biological sciences by 1989.[7] Whether this latter change occurs may depend significantly on the size of the job market created by the commercialization of biotechnology.

Social and Behavioral Sciences

Degrees in the social and behavioral sciences (limited in this report principally to psychology, economics, anthropology, sociology and political science) increased very rapidly in the late 1960's and the early 1970's, but have been dropping in recent years[20] (Figure 13). Psychology doctorates have continued to rise through 1980, but the top of the curve has probably been reached. Economic bachelor's degrees are again rising after dropping from 1970 to 1975, but the remainder of these fields continue downward.

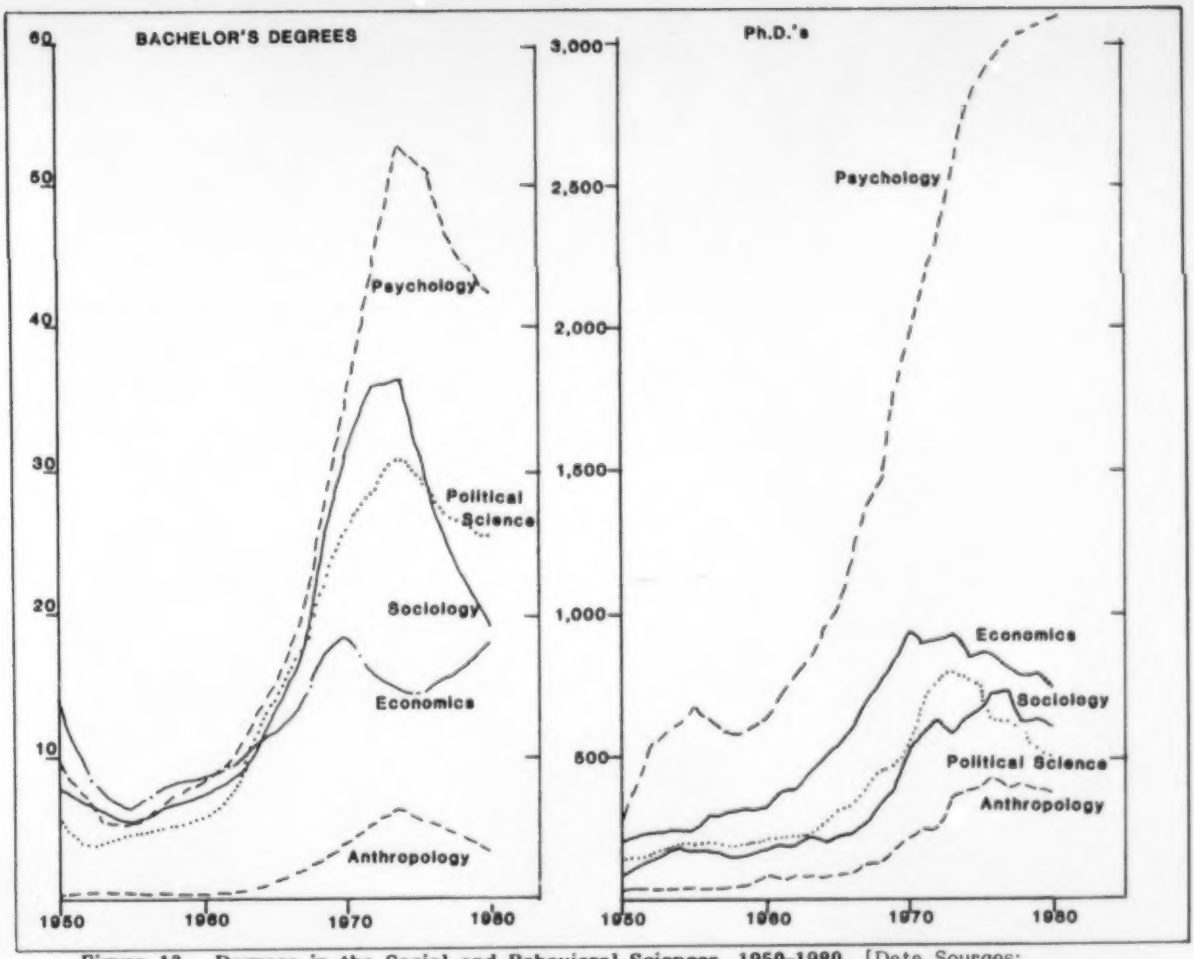

Figure 13. Degrees in the Social and Behavioral Sciences, 1950-1980 [Data Sources: National Center for Education Statistics and National Research Council]

Social and behavioral science degrees represented 37.6% of all science and engineering bachelor's degrees awarded in 1980,[4] and 38.7% of all the S/E doctorates.[5] Among women S/E graduates, those in the social and behavioral sciences are an even larger fraction of the total - 53.0% at both the bachelor's and doctoral levels in 1980.

Of all social and behavioral science degrees awarded from 1975 to 1980, women earned 46.7% of the bachelor's and 29.8% of the Ph.D.'s. Their largest representation is in psychology and the lowest in economics.[20]

Both social science and psychology degrees are projected by the National Center for Education Statistics to continue downward through 1989 at all degree levels.[7] The total drop from 1978 to 1989 is projected at 31% at the bachelor's level, 13.9% at the master's and 14.2% at the doctoral level.

Degree Summary

Although the total number of science and engineering degrees awarded is expected to drop through most of the 1980's, some fields will drop much more slowly than others, and one will continue to rise. The number of degrees awarded in the computer sciences can be expected to continue upward throughout the decade if demand for the services of these graduates remains high. All other fields probably will experience some decreases by the end of the decade. However, if the pattern of the past two decades persists in the eighties, 30% to 34% of all bachelor's graduates over the decade will receive their degree in a science or engineering field. The National Center for Education Statistics projects the total number of bachelor awards in 1989 to range from a low of 755,600 to a high of 1,130,400. The intermediate projection is for 891,800 bachelor's degrees,[7] of which 250,000 to 285,000 should be awarded in some field of science or engineering (Figure 6).

The number of S/E doctorates to be awarded over the next decade is somewhat more difficult to project because it is affected not only by the number who attain bachelor's degrees in these fields, but by the job market for both bachelor's and doctoral graduates. It will also be affected by the numbers of foreign students admitted. The present shortage of doctoral candidates in engineering and computer science, for example, is not the result of low demand for these doctorates, but rather of high demand for baccalaureate level graduates in these fields. On the other hand, the decrease in the number of Ph.D.'s awarded in recent years in most of the social sciences probably is more related to decreasing demand for doctorates in these fields, particularly in academic institutions, than to any other factor.

The population of 30-year olds (the median age of doctorate recipients in the sciences) will not begin to decline until 1991. Thus, whether the number of S/E doctorates awarded increases or decreases over the decade will be more dependent on other factors than on the size of the age group.

NCES projects total doctoral awards in 1989 at between 23,100 and 39,550.[7] The intermediate projection of 27,950 represents a drop of about 10% from 1980.[5] Between 40% and 50% of the degrees awarded probably will be in S/E fields (Figs. 6 and 9).

Immigrants

A second source of supply of scientists and and engineers is immigrants from other countries. Present U.S. immigration policy allows a maximum of 170,000 persons from the eastern hemisphere nations and 120,000 from western hemisphere nations to enter the United States each year. Nations in the eastern hemisphere are limited to 20,000 for each country, but western hemisphere nations do not have specific quotas. Preference for immigration is given in order to unmarried children and grandchildren; spouses, children and grandchildren of resident aliens; immigrants in professions; married children of U.S. citizens and their families; brothers and sisters of U.S. citizens and their families; other workers; refugees; and those with none of the above preferences.

Professionals seeking to enter the U.S. to work in a specific occupation must obtain a "labor certification" showing that the Secretary of Labor has determined that the entry of the person to work in a specific occupation will not adversely affect the wages and working conditions of U.S. workers similarly employed. About 30% of immigrant scientists and engineers receive worker certifications.

Persons may be admitted on a permanent basis, or on a temporary basis for a specific purpose such as travel or study. Those allowed to stay permanently are designated as "immigrants" and those admitted temporarily, "non-immigrants" in this report. Non-immigrants may later become permanent immigrants.[21]

Total numbers of immigrant and non-immigrant scientists and engineers from 1966 to 1978 are shown in Table 14.

Engineering is the dominant field of specialization of these scientists and engineers in 1976, 1977 and 1978, although the proportion of non-immigrants who are engineers is somewhat lower than that of the immigrant group. The number of computer specialists is increasing as a proportion of the total in both groups. Electrical engineers predominate among the engineers, chemists among the natural scientists, and economists among the social scientists (Table 15). Among the immigrant scientists in 1978, 26.7% were women as were 9.7% of the engineers.[21]

Relatively few of the non-immigrant scientists and engineers are admitted as temporary workers performing services for which no U.S. workers are available. In 1976, only 6% of the non-immigrant entrants were in this category, and in 1978, the proportion was less than 4%. In 1978, 42% of the non-immigrants were exchange visitors, 33.5% were intra-company transferees, 15% were temporary workers of distinguished merit and ability, and 5% were industrial trainees. Between 1966 and 1978, more than 49,000 scientists and engineers who entered the U.S. as non-immigrants had adjusted to immigrant status.

Table 14

IMMIGRANT AND NONIMMIGRANT* SCIENTISTS AND ENGINEERS: 1966-78
[in thousands]

	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976†	1977†	1978†
Immigrants	7.2	12.5	13.0	10.3	13.3	13.1	11.3	6.6	6.0	6.9	7.8	8.2	10.5
Nonimmigrants	5.5	5.4	5.6	5.4	6.6	2.4	2.7	4.1	4.9	5.5	6.3	6.8	4.6

† Includes computer specialists.
* Excludes students

Source: Immigration and Naturalization Service and National Science Foundation

Table 15

IMMIGRANT AND NONIMMIGRANT SCIENTISTS AND ENGINEERS BY FIELD OF SPECIALIZATION: FISCAL YEARS 1976, 1977 and 1978

Field of Specialization	Immigrants			Nonimmigrants		
	1976	1977	1978	1976	1977	1978
All Fields, Total	7,782	8,189	10,455	6,446	9,829	4,580
Engineers, Total	5,146	5,191	6,762	3,478	3,779	2,566
Aeronautical	32	61	75	18	63	11
Chemical	446	470	481	189	169	146
Civil	697	543	704	158	113	63
Electrical	754	680	916	247	249	168
Industrial	190	205	263	253	44	34
Mechanical	823	676	811	101	130	104
Metallurgical and Metallurgists	72	95	86	34	19	11
Mining and Petroleum	86	130	135	104	103	33
Sales	46	59	60	34	12	13
Other	2,000	2,272	3,231	2,250	2,877	1,983
Natural Scientists, Total	1,737	1,983	2,320	2,074	1,904	1,358
Agricultural Scientists	241	314	437	352	199	167
Biologists	268	325	334	288	430	285
Chemists	678	752	868	678	578	409
Geologists and Geophysicists	119	118	131	204	193	114
Mathematicians	210	228	254	140	124	62
Physicists, Astronomers and Space Scientists	174	181	208	337	297	289
Other	47	65	88	75	83	32
Social Scientists	612	645	784	608	691	371
Economists	336	374	426	460	607	273
Psychologists	131	137	206	68	40	33
Other	145	134	152	80	44	65
Computer Specialists	287	370	599	286	455	285

Source: Immigration and Naturalization Service and National Science Foundation

In 1976 and 1977, about half of all scientists and engineers from abroad who sought U.S. Labor Department worker certification were given that certification. In 1978, 76% of the 2,768 who sought such certification received it.

When we combine the 126,000 scientists and engineers admitted as immigrants between 1966 and 1978 and the 49,000 non-immigrants whose status was adjusted to immigrant, we see that 175,700 scientists and engineers from abroad enriched the U.S. science and engineering labor force during those years. Immigration data for later years are not yet available.

Transfers

Although many scientists and engineers trained in one field of science or engineering transfer into another during their working lives, relatively few enter science or engineering fields from disciplines outside of science and engineering. Even at the doctoral level, the number of such intrafield transfers is quite large.[22] For example, as shown in Table 16, about three and a half times as many Ph.D.'s are employed as computer specialists as the number who earned their degrees in that field. Among medical scientists, about twice as many indicate that employment field as those who indicate that degree field. However, less than 6% of doctoral scientists and engineers received their degree in some field other than science or engineering.

At lower degree levels, employment outside of science or engineering is common, and indeed, in some degree fields, predominant over science and engineering employment (Figure 4). Transfer into science and engineering employment after a non S/E bachelor's degree and without further formal education is rare.

Table 16

FIELD MOBILITY OF EMPLOYED DOCTORAL SCIENTISTS AND ENGINEERS, 1979

1979 Field of Employment	FIELD OF DOCTORATE											
	Total Empl.†	Math	Comp	Phys/ Astrn	Chem	Envir	Engr	Agric	Med	Biol	Psych	Soc Sci
All Fields (N)	305,900	16,200	1,800	26,600	43,400	10,000	47,300	13,700	8,500	54,500	37,400	46,500
Math.	13,600	**72.9**	4.4	1.8	0.2	0.2	0.8	0.2	0.0	0.3	0.4	1.1
Comp. Sci.	6,400	7.7	**74.8**	4.3	1.0	0.3	3.2	0.4	0.3	0.2	0.4	0.6
Phys/Astrn.	18,300	0.3	0.1	**60.2**	1.4	1.2	2.8	0.0	0.4	0.3	0.0	0.1
Chemistry	33,400	0.0	0.0	1.2	**71.8**	1.0	0.7	1.2	3.0	1.9	*	0.0
Env. Sci.	14,000	0.6	0.0	4.4	2.4	**84.2**	3.2	2.4	0.5	2.2	*	0.6
Engr.	46,900	6.5	12.2	16.1	5.4	3.9	**80.3**	0.5	0.2	0.6	0.3	0.3
Agric. Sci.	14,200	0.1	0.0	0.2	0.6	0.8	0.3	**74.9**	0.3	4.4	*	2.1
Med. Sci.	18,600	0.6	0.5	1.8	3.8	0.4	0.7	1.3	**79.8**	13.6	2.1	1.7
Biol. Sci.	45,100	2.8	0.0	1.4	4.9	2.2	0.8	11.4	10.7	**70.4**	1.3	0.5
Psychology	32,500	0.0	0.0	*	*	*	0.0	0.1	0.4	0.3	**85.3**	0.9
Social Sci.	36,200	1.2	1.3	0.5	0.2	0.7	0.8	2.0	0.3	0.4	2.2	**73.1**
Non S/E	18,100	4.2	2.5	4.8	4.9	3.1	4.8	3.6	2.1	2.8	5.1	15.5
No Report	8,600	3.2	4.1	3.3	3.4	2.1	1.7	1.9	2.1	2.7	2.8	3.5

† Includes postdoctoral appointees as well as full-time and part-time employed doctorates.
* Less than 0.1 percent.

Source: National Research Council

Upgrading

Very few scientists enter scientific employment without at least a bachelor's degree. Those few presently in the labor force who have no degree are generally older persons who entered the labor force many years ago and have learned their skills on the job.

Upgrading is more common in engineering, where 4% to 5% of the present labor force have less than a bachelor's degree.[23] Again, the majority of such workers are older men who began their employment as technicians and moved up into engineering jobs.

THE PRESENT SUPPLY

What is the total supply of scientists and engineers in the United States? This seemingly simple question, often asked of manpower specialists, is not simple at all, and the answer is uncertain.

Determining the size of the science and engineering manpower pool first requires defining the population to be counted. All persons who earn a bachelor's degree cannot be assumed to be a part of that science or engineering pool when many of them move immediately into something else. The National Science Foundation utilizes three criteria to determine whether an individual is to be counted as a scientist or engineer. Individuals are assumed to belong in the pool if they possess two or more of the following qualifications: (1) highest degree in science or engineering, (2) current or most recent employment in a science or engineering job, and (3) identification as a scientist or engineer. These criteria are more likely to exclude women than men from the pool, because, regardless of field, women are somewhat less likely than men to find science and engineering employment. NSF reports that only 57% of women versus 86% of men scientists and engineers were working in S/E jobs in 1978. More than half of employed women counted as scientists and engineers are counted because they identified themselves as scientists and engineers, in addition to holding one or more degrees in these fields. However, among all science and engineering graduates who are employed in non-S/E fields, a significant fraction identify themselves in relation to their current employment rather than to their field of degree. These individuals are dropped out of the survey population. Thus, the size of the science and engineering pool as reported by NSF (2.741 million) is only one half as large as the number of persons who have earned one or more degrees in science or engineering since 1948 (5.580 million).[4, 23]

For example, a women with a degree in chemistry who, unable to find a job in chemistry, accepted employment in a secretarial position will be counted in the NSF data as an employed scientist working in a non-S/E job if she self-identifies as a chemist. However, if she self-identifies as a secretary, she will be dropped from the survey population. More than 58,000 women earned bachelor's degrees in chemistry between 1948 and 1978, but NSF reports only 19,000 women chemists in the 1978 pool. About 233,000 men earned bachelor's degrees in chemistry during that

same period, and NSF reports 154,700 men in the chemistry pool. Thus the number of men chemists reported in the pool in 1978 is equal to two-thirds the number of chemistry bachelor's degrees awarded to men over those three decades, while the number of women chemists reported in the pool is less than one-third of the number of bachelor's degrees awarded to women. Some but not all of the difference is because more men than women earn advanced degrees in chemistry.

Other data bases result from employer or institutional responses rather than direct surveys of individual scientists and engineers. Much of the labor force data reported by the Bureau of Labor Statistics (BLS) is based on reports from employers, while degree data reported by the National Center for Education Statistics is provided by colleges and universities. Thus these data do not necessarily match data reported by the NSF. In 1978, for example, BLS reported 118,000 chemists employed including 17,000 women (14.4% of the total).[27] The NSF data for that year show 146,600 chemists in the labor force of whom only 9% are women.

These kinds of differences appear across various data sets not only because of definitional differences and differences in the reporting source of the data, but also differences in sampling procedures.

The Bureau of Labor Statistics says that there were 1,433,000 engineers, 301,000 life and physical scientists, and 278,000 social scientists employed in 1980. However, college and university teachers are listed separately and are not reported by field. If these numbers were included, the totals would be higher than is reported here.[24]

The most recent data available from the National Science Foundation[25] show that in 1980 the number of employed engineers was 1,360,000, life and physical scientists 401,000, and social scientists 99,000. Thus, the total number of scientists and engineers in the U. S. labor force cannot be stated with certainty. Employment sector, by field of U.S. scientists and engineers in 1980, as reported by the National Science Foundation, is shown in Table 17.

Table 17

EMPLOYMENT SECTOR OF U.S. SCIENTISTS AND ENGINEERS, 1980

[In Thousands]

FIELD	Employment Sector			
	Total Employed*	Business/ Industry	Educational Institutions	Federal Gov't
Scientists and Engineers, Total	2,316	1,567	352	173
Scientists, Total	956	466	297	82
Physical Scientists	200	111	56	14
Chemists	137	88	28	7
Physicists/Astronomers	47	16	24	5
Other Physical Scientists	16	7	3	2
Mathematical Scientists[1]	47	18	23	3
Computer Specialists	259	192	23	15
Environmental Scientists	72	40	14	11
Earth Scientists	63	37	12	8
Other Environmental Scientists [2]	10	3	2	3
Life Scientists	201	53	88	30
Biological Scientists	71	10	50	5
Agricultural Scientists	84	38	13	23
Medical Scientists	45	5	25	2
Psychologists	78	23	45	2
Social Scientists	99	31	50	6
Economists	38	17	15	4
Sociologists/Anthropologists	11	2	7	1
Other Social Scientists	50	11	27	2
Engineers, Total	1,360	1,091	55	91

* Includes those employed in all other sectors.

1 Includes mathematicians and statisticians.

2 Includes oceanographers and atmospheric scientists.

Source: National Science Foundation

The doctoral workforce in science and engineering is of specific interest in relation to academic and research activities. Most of the faculty in U. S. universities have doctorates, and Ph.D.'s direct most of U. S. research activities, whether carried out in academic institutions, government, or business and industry.

The doctoral population has been surveyed biennially by the Commission on Human Resources of the National Research Council since 1973.[26] The number of employed doctorates in science and engineering increased from 262,991 in 1975 to 305,900 in 1979, a net increase of 16.3% in four years, or about 4% per year. By field of employment, the largest increases were in the medical sciences and in the group of scientists and engineers who are employed in non-science areas. The smallest increases were in chemistry, physics and agriculture. Whether the fields of employment that have grown fastest during that period will continue to show the fastest growth over the coming decade is not certain.

By field, the science and engineering population varies widely in the level of formal education achieved. In 1978, the proportion with doctorates ranged from less than 3% of computer specialists and 3.5% of engineers to 36.5% of physicists and astronomers[23] (Fig. 14). Agricultural scientists, computer scientists and engineers were the most likely to have only a bachelor's degree, while psychologists and biological scientists were least likely to have stopped their formal education at that degree level.

The educational level of the science and engineering population is rising in most fields, and probably will continue to increase through at least the first half of the 1980's.

DEMAND

Demand for scientists and engineers, either present or future, can be defined in several ways, and no single definition is common across the statistical data available. Is present demand exactly equal to the number of persons employed in any particular field? Is it some combination of the number employed plus the number of unfilled openings? Must these openings have remained unfilled for some specified period of time?

Equally difficult is the assessment of imbalance between supply and demand. Would supply and demand be in perfect balance if the unemployment rate among scientists and engineers were zero, or would perfect balance require that all qualified scientists and engineers who wanted employment in science and engineering jobs were so employed? When there is a low but existing unemployment rate, plus a significant fraction of scientists and engineers employed in non- S/E jobs, plus a large number of advertised but unfilled S/E jobs - a combination existing in late 1981 - are supply and demand in or out of balance? If they are out of balance, is the problem one of oversupply of scientists and engineers, undersupply of science and engineering employment, or a combination of both which varies by science or engineering field?

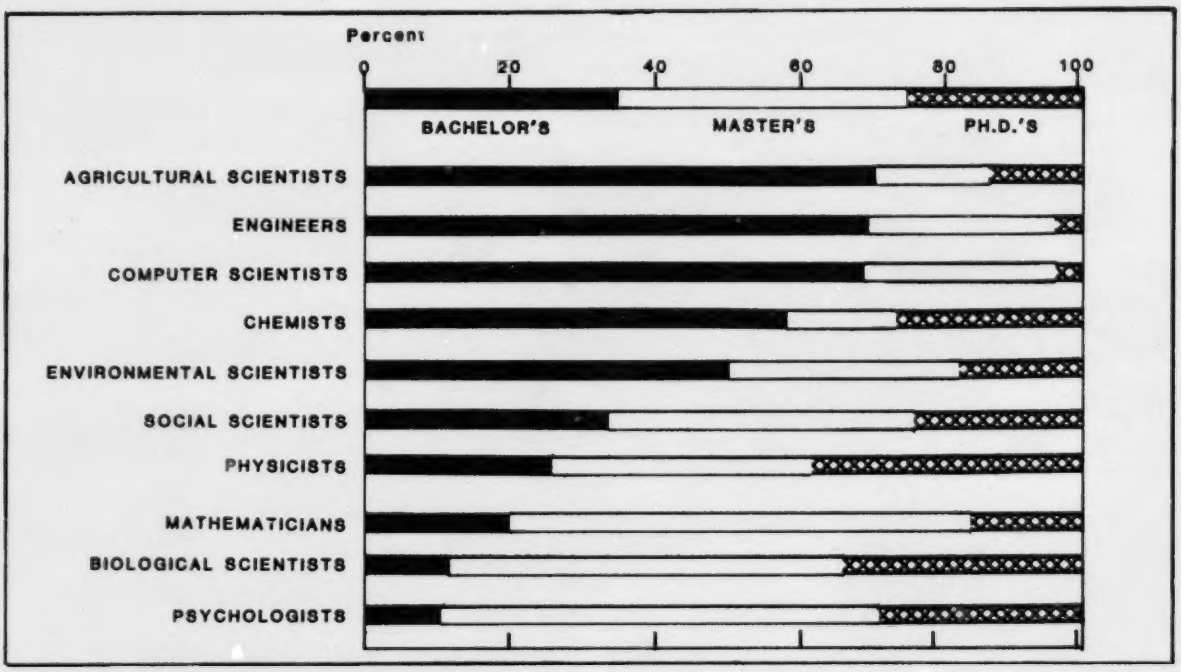

Figure 14. Highest Degree Level of Scientists and Engineers [Data Source: National Science Foundation]

The problem of determing balance in supply and demand is compounded by the fact that there are different markets for experienced and inexperienced scientists and engineers. These two markets operate differently and often independently, employing different recruitment methods and different employment techniques. It is not uncommon for a company to be actively recruiting new science and engineering graduates even as they are laying off some experienced scientists and engineers. Among the principal reasons for this dichotomy is that different kinds of jobs are involved in the two markets. New scientists or engineers are needed for entry level positions with high technical content, and for management training. Openings for experienced engineers and scientists usually are more specific in terms of job requirements, particularly on the technical side. Older scientists and engineers sought for management positions may be required to have extensive experience in a particular industry or product area.

Additional factors that enter the hiring picture are the relative differences in the cost of employing new graduates compared with those who have several years of experience; and the adaptability of new graduates, not only in terms of technical work placement but in their easier ability to make geographic shifts. Thus, the job market for new graduates is often out of phase with that for experienced scientists and engineers. This is more likely to produce career instability in some fields than in others, and may be a factor in the choices made by entering students.

The unemployment problems of older engineers, physicists and chemists in the early part of the 1970's had an obvious impact on the career choices of young people which showed up in falling enrollments in physical sciences, and for shorter times in engineering, during a decade of generally rising enrollments.

Demand for New Graduates

Two long-term ongoing surveys measure demand for new graduates. The College Placement Council (CPC) reports three times in each year, with final reports in July on the number and size of job offers made to graduating students.[27] Once a year, CPC reports the actual number of hires in the previous recruiting year plus the number of positions that are expected to be available over the coming year in a broad sample of employers in business, industry, government, and non-profit and educational institutions.[28] Teaching positions are not included. This

Table 18

NUMBER OF HIRES BY CURRICULAR GROUPINGS AND DEGREE LEVELS

	Bachelor's		Master's		Doctoral		Curriculum Total†		
	No. Hires 1981-82 [5]	No. Hires 1980-81 [6]	No. Hires 1981-82	No. Hires 1980-81	No. Hires 1981-82	No. Hires 1980-81	No. Hires 1981-82	No. Hires 1980-81	Percent Change
ENGINEERING [1]	28,101 (404)	25,075 (389)	3,128 (203)	2,378 (187)	819 (109)	598 (89)	32,048	28,051	+14%
SCIENCE, MATH & OTHER TECHNICAL [2]	11,872 (375)	9,684 (360)	2,249 (157)	1,742 (159)	1,250 (86)	947 (90)	15,371	12,373	+24
BUSINESS [3]	28,286 (453)	24,967 (441)	6,376 (234)	5,528 (230)	44 (12)	44 (14)	34,706	30,539	+14
OTHER NON-TECHNICAL [4]	5,847 (250)	5,563 (266)	411 (59)	469 (74)	68 (18)	85 (24)	6,326	6,117	+3
DEGREE TOTAL	74,106	65,289	12,164	10,117	2,181	1,674	88,451	77,080	+15

( ) Figures in parentheses are number of employers reporting hires in that category.

[1] Includes engineering technologies.

[2] Includes computer science.

[3] Includes accounting, marketing, business management, finance, etc.

[4] Includes liberal arts, humanities, social sciences, home economics, etc.

[5] Actual and anticipated hires.

[6] Actual hires.

† Final totals represent data reported by 551 employers.

Source: College Placement Council

annual report compares the number of hires in the previous year with those expected for the present year in four broad discipline categories at all degree levels: engineering, science-math-other technical, business, and other non-technical.

The October 1981 survey[28] reports that the 551 employing organizations in the private sector that responded to the CPC survey anticipate increased hiring in 1982 for each of the four curricular areas surveyed (Table 18). The anticipated increase in engineering hires from 1981 to 1982 is 12% at the bachelor's level, 32% at the master's, and 37% at the doctoral level; while the science, math and other technical group (which includes computer science, chemistry, physics, geology, etc.) shows increases of 23%, 29%, and 32% at succeedingly higher degree levels. For the first time in four years, these companies anticipate an increase in hiring even in the other non-technical category.

• A second survey, conducted annually for 35 years by Frank S. Endicott at Northwestern University,[29] reports on trends in the employment of college and university graduates for the year, from survey responses collected in October and November of the previous year. The Endicott Survey anticipated an increase in hiring for science and engineering from 1980 to 1981, and that increase did occur.

• The Engineering Manpower Commission examines the placement of new engineering graduates each year.[30] Table 19 shows the placement status of these graduates in 1980 and Figure 15 compares bachelor's graduates over the period from 1969 to 1980 as to their status at the approximate time of graduation. The proportion entering full-time graduate study has dropped from 20% in 1975 to 12% in 1979 and 1980, and the proportion with neither offers nor plans dropped from 12% in 1975 to 3% in 1979, rising to 5% in 1980.

Table 19

PLACEMENT STATUS OF ENGINEERING AND TECHNOLOGY GRADUATES

	Engineering Degree			Technical Degree	
	B.S.	M.S.	Ph.D.	A.A.	B.S.
Newly Employed	73%	61%	80%	55%	73%
Returning to Job	2	12	12	7	9
Full-Time Study	12	18	0	19	3
Other Plans	5	5	3	5	5
Considering Job Offers	3	2	3	4	1
No Offers or Plans	5	2	2	10	9

Source: Engineering Manpower Commission

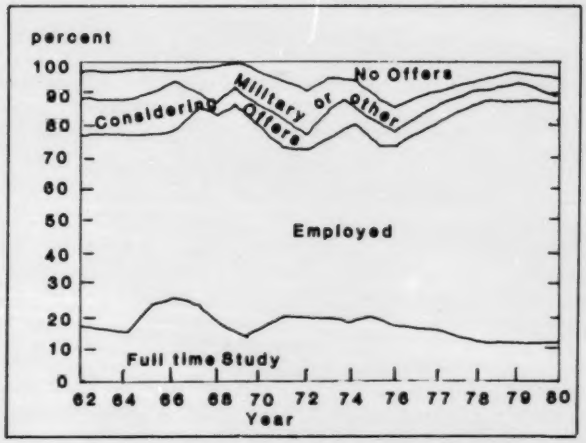

Figure 15. Placement Status of B. S. Engineering Graduates, 1962-1980 [Source: Engineering Manpower Commission

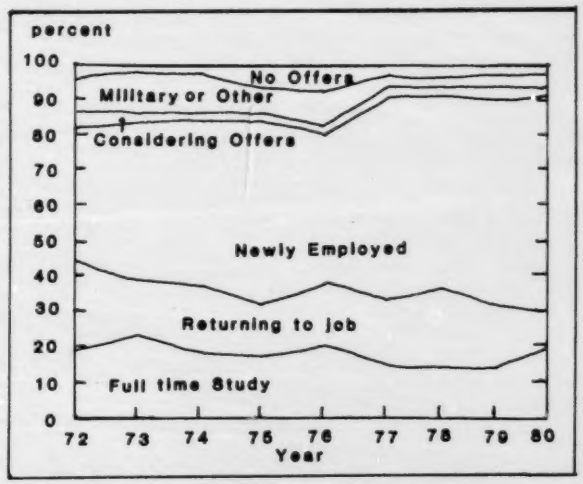

Figure 16. Placement Status of M.S. Engineering Graduates, 1972-1980 [Source: Engineering Manpower Commission]

The number of master's graduates going on to full-time study rose from 16% in 1979 to 18% in 1980 while the proportion with neither offers nor plans dropped from 3% to 2% (Fig. 16).

Large differences in the proportion of the graduates who have accepted employment occur in the various subfields of engineering. While 99% of the B.S. petroleum engineers had accepted a job offer or were already employed and returning to the job at the time of graduation, only 52% of B.S. graduates in engineering science and general engineering were in this category. Much higher proportions of the engineering science and general engineering majors were continuing in graduate study. Although less than one percent of the nuclear or ocean engineering graduates were seeking work and had no offers, the proportion ranged as high as 27% among architectural engineers (Table 20).

Table 20

PLACEMENT STATUS OF B.S. GRADUATES BY ENGINEERING CURRICULUM, 1980

FIELD	Total No. with Status Known	Percent: Accepted Job Offer	Employed Return. to Job	Full-Time Study	Other Specific Plans	Considering Job Offers	No Offers, Seeking Work
All Engineers	23,970	73%	2%	12%	5%	3%	5%
Aeronautical	401	66	4	13	8	6	3
Agricultural	320	66	*	15	6	3	9
Architectural	291	53	4	7	5	4	27
Ceramic	186	59	1	23	4	1	13
Chemical	3,041	77	1	11	4	2	5
Civil	3,547	71	2	12	4	4	6
Computer	726	78	1	10	7	1	3
Electrical	5,376	75	3	11	5	2	4
Engr. Science	537	51	1	35	5	4	4
General	373	51	1	30	7	6	6
Industrial	1,077	76	2	10	4	3	5
Mat. Sci. & Engr.	201	69	1	18	4	2	5
Mechanical	5,253	78	1	10	5	2	4
Metallurgical	381	67	1	15	5	6	6
Mining/Geological	1,486	73	4	11	5	2	6
Nuclear	15	60	*	7	33	*	*
Oceanographic	91	57	7	35	*	1	*
Petroleum	93	98	1	*	*	*	1
Systems	51	71	*	20	*	*	10
Other	524	70	5	12	5	2	7

* Less than one percent.

Source: Engineering Manpower Commission

The fact that an engineering graduate did not have a job as of the date of graduation does not necessarily mean that he or she entered long-term unemployment. Each year, placement officers report that many new graduates wish to remain uncommitted through the summer and that by fall practically all new engineers actively seeking work will have found a job. Nonetheless, the percentage of those still "considering job offers" had decreased in 1980,perhaps indicating that the demand for graduates was softening and that the 1980 graduates did not take as much time deciding on their final choice. The Bureau of Labor Statistics reported an overall unemployment rate for engineers of only 1.3 for 1980 and 1.5%, 1.4% and 1.3%, respectively, for the first three quarters of 1981.

• Similar information on the plans of physics graduates[3] shows that at the time of graduation, 14% of the bachelor's graduates in 1980 who planned immediate employment had no job offers, down from 26% in 1973. Among terminal master's graduates, 9%

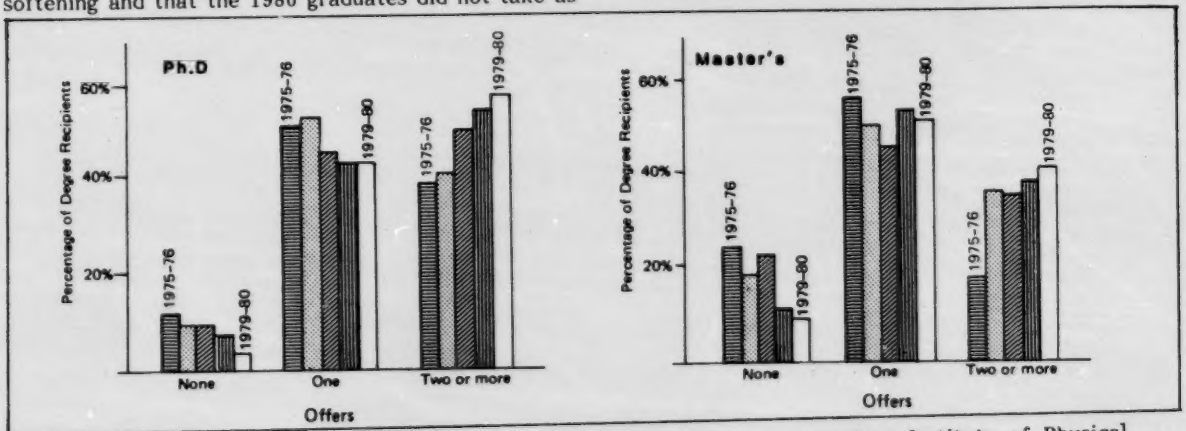

Figure 17. Employment Offers for New Physics Graduates [Source: American Institute of Physics]

were seeking employment and had no job offers, and among new doctorates, 2% had no offers at the time the degree was awarded (Fig. 17). However, the unemployment rate for members of the American Institute of Physics fell below 1% in 1980.[32]

Comparable information on the placement of new graduates in other fields is not available. However, the NSF studies of employment characteristics of recent graduates indicate that unemployment rates are lower for engineers than for scientists (Fig. 3), and that employment in science or engineering jobs is far less likely for scientists at the bachelor's level and somewhat less likely at the master's level than for engineers (Fig. 4).

Starting salary data, another indicator of demand, show that engineers continue to top all bachelor's degree graduates in terms of beginning salary levels, and are about equal at the master's and doctoral levels to physical and computer scientists (Table 21.)

Table 21

AVERAGE MONTHLY STARTING SALARY OFFERS, SELECTED FIELDS, 1981

FIELD	Degree Level		
	Bachelor's	Master's	Ph.D.'s
Engineering			
Chemical	$2,030	$2,207	$2,745
Civil	1,775	2,033	2,523
Electrical	1,882	2,138	2,793
Mechanical	1,908	2,125	2,659
Metallurgy	1,914	2,117	2,575
Mathematics	1,624	1,929	
Computer Science	1,726	2,057	2,573
Chemistry	1,637	1,967	2,481
Earth Science	1,846	2,110	
Humanities	1,204	1,406	
Social Sciences	1,245	1,417	
Business	1,356	1,652	

Source: College Placement Council

The percentage distribution of job offers and of hires in the companies reporting to the College Placement Council for 1980[33] is shown in Table 22, which also provides information on the percentage distribution of graduates in those broad curricular groups. These data indicate that engineering graduates had their choice of several offers, as did graduates in the various business areas. Hires in the science and math and the social science and humanities groups were higher as a proportion of total hires than their proportion of total offers, except for baccalaureate business graduates. However, the distribution of degrees differs markedly from the distribution of hires by this group of employers, particularly in engineering.

As has been pointed out in several studies by the Bureau of Labor Statistics,[34] the economy has been unable since the early seventies to absorb all college graduates in jobs typically requiring a college degree. Both engineering graduates and those in science and mathematics obviously have a considerably easier time finding employment related to their fields than do graduates in the social sciences and humanities.

Even at the doctoral level, this continues to be true. Among the 1980 Ph.D. graduates, 19.1% were still seeking employment at the time the doctorate was awarded, including 10.3% of the physical scientists, 15.4% of engineers, 11.1% of life scientists, and 22.1% of social and behavioral scientists. In the non-science areas, 24.1% of the graduates were still seeking employment at the time of the degree award.[16]

Demand for Experienced Scientists and Engineers

Employment of experienced scientists and engineers as well as other professionals is measured by the Bureau of Labor Statistics in its monthly surveys of about 40,000 households, but the figures are aggregated into the category "professional and technical workers" which includes many persons who are not scientists and engineers. The unemployment rate for this larger category was 3.2% in 1975 and 3.1% in 1976 before dropping to 2.2% in 1979 and 2.3% in 1980[35] (Fig. 1). Unemployment for this group averaged 2.6% in the first eight months of 1981.

Table 22

DISTRIBUTION OF COLLEGE GRADUATES, JOB OFFERS AND HIRES BY CURRICULUM GROUP, 1980

	Degree Level					
	Bachelor's			Master's		
	Degrees	Offers	Hires	Degrees	Offers	Hires
Engineering	7%	63%	38%	5%	27%	23%
Science & Math	12	8	15	7	10	17
Business	20	25	38	19	61	55
Social Sciences & Humanities	26	4	9	14	2	5

Sources: College Placement Council and National Center for Education Statistics

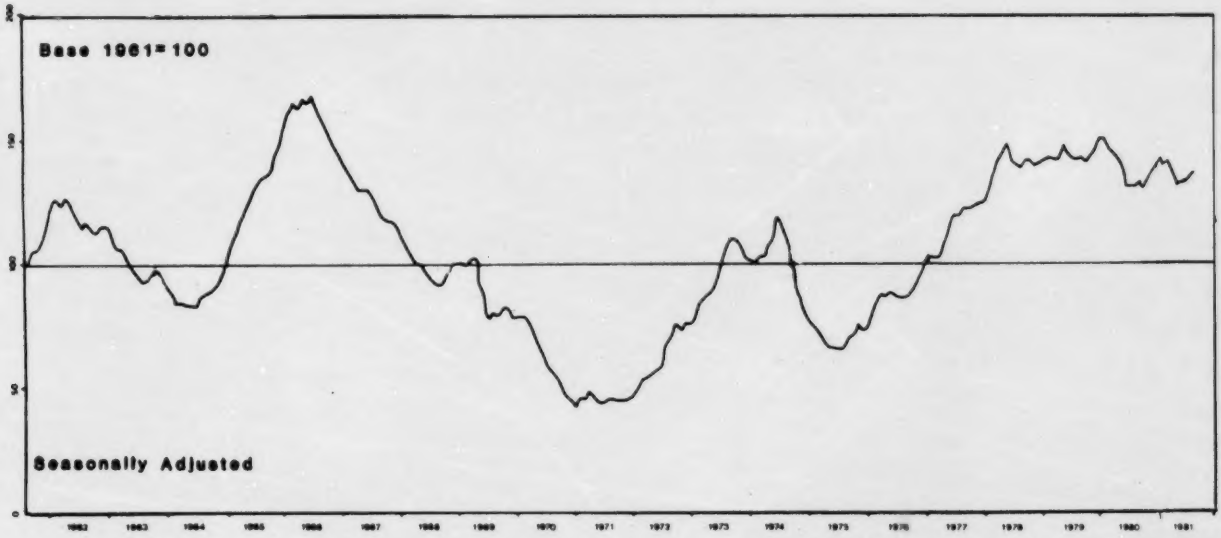

Figure 18. Deutsch, Shea & Evans High Technology Recruitment Index [Source: Deutsch, Shea & Evans]

Engineering employment and unemployment is calculated quarterly from this BLS survey. That unemployment rate was 1.2% in 1979, 1.3% in 1980 and 1.5%, 1.4% and 1.3% respectively in the first three quarters of 1981.[36]

Another comparative index of demand for scientists and engineers is the High Technology Recruitment Index maintained by the advertising firm of Deutsch, Shea and Evans. This index measures classified advertising for scientists and engineers in newspaper display ads, newspaper classified ads and technological journals. The index, maintained monthly since 1961, has remained high since 1978, in contrast to the low demand index through the period of the early and mid-seventies (Fig. 18).

Academic Demand

The number of scientists and engineers employed full time at colleges and universities increased 14.5% from 1975 to 1980, rising from a total of 223,336 in 1975 to 255,659 in 1980, according to surveys by the National Science Foundation[37] (Table 23). Some employment fields grew much faster than others over that five-year period, and employment in some fields actually dropped between 1978 and 1980. The proportion of women among academically employed scientists and engineers increased slightly in almost every field but rose only two percentage points in five years for total science and engineering employment.

Total academic employment in science and engineering is expected to hold steady or decline through at least 1985 as the size of the college-age population drops. Significant increases in federal budgets for research would tend to maintain a stable size in the total science and engineering population in academic employment, although the emphasis of such research might significantly alter the present proportions in each major field group. These proportions have not changed substantially over the past five-year period, although there are modest increases in the proportion of the total made up of engineers, computer scientists, environmental scientists and life scientists. Small drops in proportion have occurrred in the physical sciences, mathematics, psychology and the social sciences.

The lack of substantial growth in science and engineering faculty has resulted in a highly tenured faculty in science and engineering with little room for input of new doctorates. The proportion of recent doctorates - those holding their degrees for seven years or less - on the full-time faculty of science and engineering departments in Ph.D.-granting institutions has dropped from 39% in 1968 to 28% in 1974 and to 21% in 1980.[38] The percentage of faculty with tenure rose from 70% in 1974 to 74% in 1980, ranging from 59% in computer science to 83% in physics.

Demand for Scientists and Engineers in Research and Development

The total number of full-time equivalent R & D scientists and engineers reached a new all time high of 659,500 in 1980, according to estimates by the National Science Foundation[39] (Table 24). Industry is by far the largest employment sector.

In 1980, in all employment sectors combined, 694,000 U.S. scientists and engineers (30% of all scientists and engineers) worked principally in research or development or the management or administration of R & D.[25] By employment sector, 72.6% were in business and industry, 11.8% in educational institutions, 6.8% in federal employment, and 8.8% in other employment settings.

Table 23

FULL-TIME SCIENTISTS AND ENGINEERS EMPLOYED IN COLLEGES AND UNIVERSITIES, JANUARY 1975, 1978, 1980

FIELD	1975		1978		1980		1975-80
	Total	% Women	Total	% Women	Total	% Women	Avg. Ann. % Increase Total
TOTAL	223,336	15.0	242,063	16.1	255,659	17.3	2.9
ENGINEERS	22,580	1.6	24,667	2.4	26,525	2.7	3.5
Aeronautical/Astronautical	944	2.6	964	1.9	1,144	2.4	4.2
Chemical	1,603	1.6	1,722	1.8	1,893	3.1	3.6
Civil	3,832	1.6	4,242	3.0	4,332	2.7	2.6
Electrical	5,393	1.1	5,596	1.6	6,398	1.8	3.7
Mechanical	4,355	.7	4,532	1.3	4,809	1.9	2.1
PHYSICAL SCIENTISTS	26,662	7.5	27,890	8.8	28,101	8.9	1.1
Chemists	13,823	10.3	14,735	11.7	14,392	12.4	0.8
Physicists	10,940	3.5	11,268	4.3	11,417	4.4	0.9
ENVIRONMENTAL SCIENTISTS	6,787	4.7	8,169	6.9	8,315	7.9	4.5
Earth	5,172	4.3	5,960	6.9	5,566	7.2	1.5
Atmospheric	559	6.1	821	4.3	786	5.5	8.1
Oceanographic	1,056	5.9	1,388	8.7	1,387	9.0	6.3
MATHEMATICIANS	18,699	13.2	19,567	14.9	19,916	16.0	1.3
COMPUTER SCIENTISTS	3,705	12.0	4,782	11.7	6,131	14.8	13.1
LIFE SCIENTISTS	90,684	19.9	97,749	20.4	108,619	22.3	4.0
Agricultural	13,235	11.7	13,705	9.0	14,429	9.2	1.8
Biological	33,462	18.9	37,656	20.7	38,840	21.2	3.2
Medical	43,987	23.1	46,278	23.6	50,783	23.4	3.1
PSYCHOLOGISTS	15,973	22.4	17,413	24.8	16,756	25.8	1.0
SOCIAL SCIENTISTS	38,246	16.7	41,826	18.1	41,296	19.0	1.6
Economists	10,169	8.5	10,851	8.9	11,118	10.0	1.9
Sociologists	10,744	24.6	11,505	26.3	10,859	27.1	0.2
Political Scientists	8,687	10.3	9,055	11.9	8,840	12.7	0.4

Source: National Science Foundation

Science and engineering employment in research and development is, of course, tied directly to R & D funding. National spending on R & D is expected to reach a record 79 billion dollars in 1985, more than double the total for 1975, according to the National Science Foundation.[40] R & D funds by source and performer are shown in Table 25.

Both the size of future R & D budgets and the effects of inflation on the cost per R & D scientist and engineer will be determinants of R & D employment through the eighties. Neither of these factors can yet be projected with any clarity.

PROJECTIONS OF SUPPLY/DEMAND IMBALANCES

Estimates of long range future demand usually are either projections based on past trends which incorporate certain demographic statistics, or surveys based on the hiring plans of major employers.

• The Bureau of Labor Statistics (BLS) regularly forecasts employment trends ten years ahead, using economic trend models hedged by consideration of expected federal R & D budgets, defense expenditures, and industrial expansion to meet demand for more goods and services. Estimates are provided as averages over a decade, without specific reference to the irregularly spaced dips and rises in demand which occur repeatedly in engineering and scientific employment.

In examining the outlook for all college graduates relative to these demand projections, BLS points out that only 46% of college graduates found professional and technical jobs in the period between 1969 and 1978.[34] About 20% entered managerial jobs and another 9% entered sales jobs. However, about one-fourth of the graduates spilled over into occupations not previously sought or filled by college graduates including clerical, blue collar, service and farm

Table 24

FULL-TIME EQUIVALENT (FTE) SCIENTISTS AND ENGINEERS EMPLOYED IN R & D BY SECTOR: SELECTED YEARS[1]

[in thousands]

Sector	1954	1961	1965	1969	1972	1974	1975	1976	1977	1978	1979[2]	1980[2]
Total	237.1	425.7	494.5	555.2	518.3	525.1	534.9	549.2	573.9	601.6	629.5	659.0
Federal Gov't.[3]	37.7	51.1	61.8	68.5	64.4	62.6	63.4	64.0	64.7	65.4	66.0	66.5
Industry[4,5]	164.1	312.0	348.4	385.6	353.9	361.6	363.8	373.6	393.2	415.8	440.0	465.0
Universities & Colleges, Total	25.0	42.4	53.4	68.3	66.5	65.5	70.2	71.8	74.5	77.7	80.0	82.5
Sci. & Engrs.	20.3	33.6	40.4	50.4	48.9	48.0	51.6	52.9	54.4	57.1	59.0	60.5
Grad. Stud.[6]	4.7	8.8	13.0	17.9	17.6	17.5	18.6	18.9	20.1	20.6	21.0	22.0
University-Associated FFRDC's, Total	5.0	9.1	11.1	11.6	11.7	12.1	12.7	13.4	14.0	14.7	15.0	16.0
Sci. & Engrs.	4.9	8.8	10.7	11.1	11.3	11.8	12.3	13.0	13.6	14.3	14.6	15.6
Grad. Stud.[6]	.1	.3	.4	.5	.4	.3	.4	.4	.4	.4	.4	.4
Other Non-Profit Institutions[4]	5.3	11.1	19.9	21.2	21.8	23.3	24.8	26.4	27.5	28.0	28.5	29.0

1 Number of full-time employees plus the FTE of part-time employees. Excludes scientists and engineers employed in state and local government agencies. Totals may be understated by about 5 percent because of incomplete data on summer employment at universities and colleges.

2 Estimate.

3 Includes both civilian and military service personnel and managers of R&D.

4 Includes professional R&D personnel employed at FFRDC's administered by organizations in the sector.

5 Excludes social scientists.

6 Numbers of FTE graduate students receiving stipends and engaged in R&D.

Source: National Science Foundation

occupations. The unemployment rate for all graduates increased from less than 1% in early 1969 to 2.5%, and for graduates 20-24 years old, from 2.4% to 6.1% by 1978.

Although the proportion of the population 18-21 years old will decline during the 1980's, college enrollments are projected to stay approximately level as the drop in the number of students of typical age is offset by growth in the number of older students in college. The 1980's graduates are expected to face job market conditions similar to those faced by graduates during the 1970's as entrants continue to exceed openings in jobs traditionally sought by college graduates. As a result, about one graduate in four will have to enter a non-traditional occupation or face unemployment.

About 13.5 million college graduates will enter the labor force from 1978 to 1990, but only 10.2 million job openings are expected to be available in traditional jobs for graduates.[34] About half of the openings are expected to result from growth in the kinds of jobs filled by gradyates in the past and from upgrading jobs, and the other half from the need to replace graduates who retire, die or leave the labor force for other reasons.

However, graduates in some fields of study are expected to be in balance with the number of openings available. Figure 19 shows average annual graduates, by degree level and average annual openings (degree level unspecified) for 1978 to 1990, by field, for scientists and engineers. In some fields, the total number of openings is sufficient to absorb all of the doctoral graduates, the master's graduates, and some proportion of the bachelor's graduates. These include engineering, chemistry, economics, geology and geophysics. Job openings for computer professionals will exceed the total of all degrees awarded at all levels. In the life sciences, psychology, and mathematics/statistics, the openings should be able to absorb the Ph.D.'s and most of the master's graduates. However, among political scientists and sociologists, the number of openings is expected to be below even the number of Ph.D.'s awarded. Other fields, including education and the humanities, indicate far larger numbers of extra graduates in relation to job openings than do any of the science or engineering fields.

Table 25

FUNDS FOR RESEARCH AND DEVELOPMENT

[Millions of dollars]

Year	Total	Federal Government	Industry[1]	Academic Sector		Other Nonprofit Inst.[1]
				Universities & Colleges	Associated FFRDC's[2]	
			By Performer			
1975	$35,169	$ 5,310	$24,187	$3,409	$ 987	$1,276
1976	38,935	5,688	26,997	3,727	1,147	1,376
1977	42,923	6,053	29,928	4,063	1,384	1,495
1978	48,023	6,856	33,164	4,614	1,717	1,672
1979	54,215	7,497	37,606	5,183	1,935	1,994
1980 (prel.)	61,127	8,052	42,750	5,950	2,200	2,175
1981 (est.)	69,065	8,965	49,150	6,300	2,300	2,350
1982 (est.)	79,000	10,100	57,000	6,800	2,350	2,750
			By Source			
1975	35,169	18,065	15,820	749	-	535
1976	38,935	19,833	17,694	808	-	600
1977	42,923	21,674	19,696	881	-	672
1978	48,023	23,893	22,336	1,028	-	766
1979	54,215	26,556	25,638	1,183	-	838
1980 (prel.)	61,127	29,302	29,475	1,385	-	965
1981 (est.)	69,065	32,665	33,865	1,485	-	1,050
1982 (est.)	79,000	37,600	38,600	1,550	-	1,250

[1] Includes expenditures for federally funded research and development centers (FFRDC's) administered by this sector. They account for less than 5 percent and 15 percent, respectively, of the industry and nonprofit performance totals.

[2] FFRDC's administered by individual universities and colleges and by university consortia.

Source: National Science Foundation

• A study prepared at the request of President Carter by the National Science Foundation and the Department of Education[41] examines supply and demand in conjunction with its overview of science and engineering education for the 1980's and beyond. Combining data from NSF, the Bureau of Labor Statistics and the National Center for Education Statistics, the report compares the number of projected job openings with the number of degrees projected from 1978 to 1990 (Table 26). The projections were made on the basis of several possible scenarios including, in addition to the base line assumptions, that there would be accelerated defense spending, a synthetic fuels program, or a balanced federal budget. The projections do not indicate any shortage of graduates at the baccalaureate level except in industrial engineering. The report does not relate degrees in computer science to job openings for computer professionals. However, degree projections in the computer sciences, as shown in Table 11, represent only a small fraction of the estimated job openings for computer professionals.

At the doctoral level, the report shows that by 1990, some 80,000 Ph.D.'s, or 18% of all doctoral scientists and engineers, will be utilized outside of science and engineering (Fig. 20). The non-S/E utilization will include 26,000 social scientists, 20,000 life scientists, 17,000 engineers, 10,000 physical scientists and 7,000 mathematical scientists. These numbers compare with 28,000 doctoral scientists and engineers in 1979 (9% of the total) who are utilized outside of science and engineering.

• Another study by the Bureau of Labor Statistics projects a 29% to 36% increase in the employment of professional, technical and related workers between 1978 and 1990. In three projections of economic growth referred to as the low-trend, high-trend I and II scenarios, BLS uses different assumptions concerning growth of the labor force, output, productivity, and other factors. The low-trend alternative assumes a decline in the rate of labor force expansion, continued high inflation, and modest increases in production and productivity. Both of the high trend alternatives are more optimistic, and are based on large increases in the gross national product. High scenario I assumes higher labor force growth while scenario II assumes greater productivity.

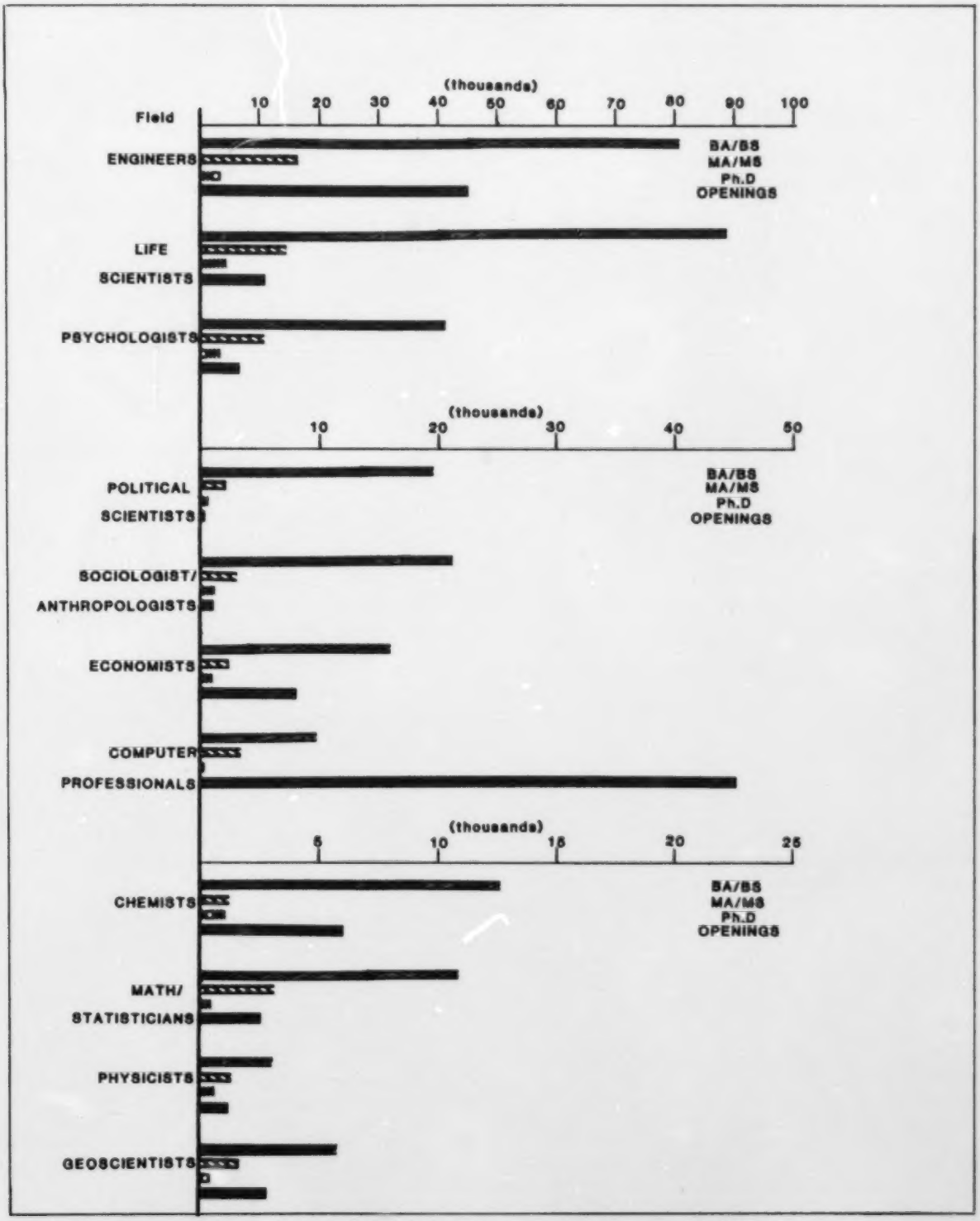

Figure 19. Projections of Openings & Degrees - Annual Averages, 1978-1990
[Data Source: Bureau of Labor Statistics]

Table 26

COMPARISONS OF PROJECTED JOB OPENINGS WITH PROJECTED DEGREES IN SCIENCE AND ENGINEERING 1978-1990

	Job Openings, 1978-1990 (in thousands) Senario				Graduates, 1978-1990 (in thousands) Level	
	Baseline Assumptions	Accelerated Defense Spending	Synthetic Fuels Program	Balanced Federal Budget	Bachelor's Degrees	Master's Degrees
Life and Physical Scientists						
Agricultural	16	16	16	16	193	34
Atmospheric	5	5	5	5	5	4
Biological	38	38	38	37	637	78
Chemical	63	64	64	63	178	26
Geological	22	22	23	22	67	18
Marine	2	2	2	2	10	3
Physics and Astronomy	11	11	11	11	45	19
Total	157	159	157	156	1,135	182
Mathematical Sciences						
Mathematicians	3	3	3	3	102	27
Statisticians	19	19	19	19	3	5
Total	22	22	22	22	105	32
Computer Professionals						
Programmers	300	302	300	299	NA	NA
Systems Analysts	221	223	221	221		
Other	28	29	28	28		
Total	549	553	550	547	110	47
Social Scientists						
Psychologists	76	76	76	75	490	111
Other[1]	100	102	101	99	628	58
Total	176	178	177	175	1,117	170
Engineers						
Aeronautical	24	35	24	24	28	NA
Chemical	22	22	22	21	92	
Civil	95	95	95	94	134	
Electrical	121	128	121	120	172	
Industrial	94	98	94	93	48	
Mechanical	89	95	89	89	171	
Metallurgical	9	9	9	9	16	
Mining	7	7	7	7	11	
Petroleum	11	11	11	11	14	
Other	59	61	59	59	115	
Total	528	561	534[2]	525	928[3]	196
Total All Fields	1,432	1,473	1,439	1,424	3,395	626

1 Includes economists, political scientists and sociologists.
2 Includes 4,000 engineers who are not distributed by field.
3 Includes 128,000 engineering technology degrees not distributed by field.

NOTE: Estimates of openings do not include academic employment. Detail may not add to totals because of rounding.

Sources: National Science Foundation, Bureau of Labor Statistics and National Center for Education Statistics

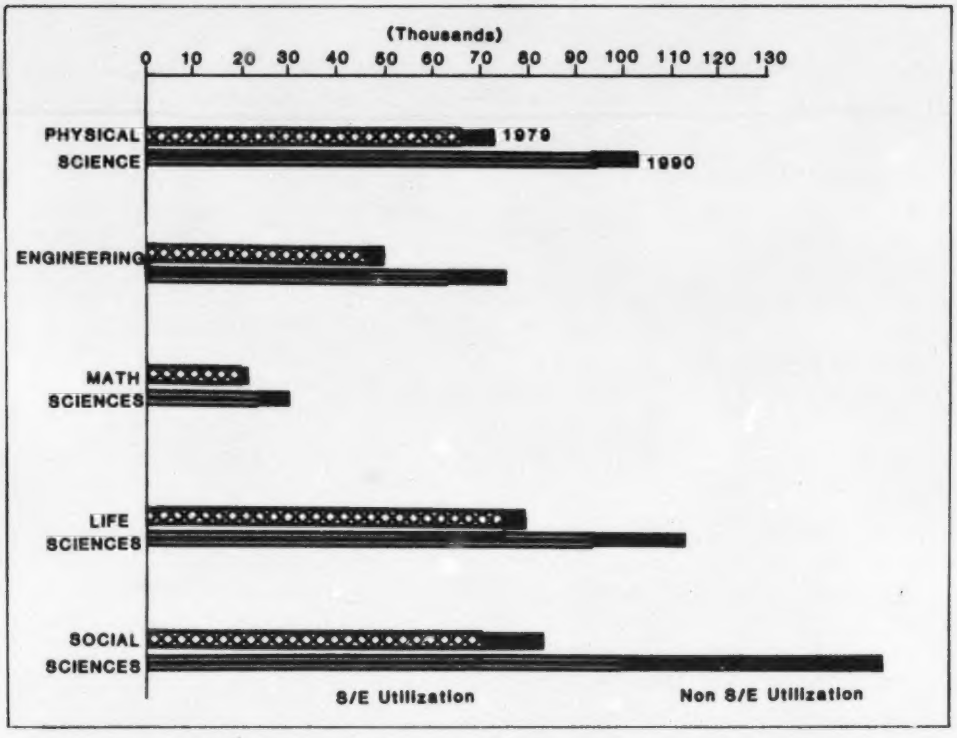

Figure 20. S/E Utilization of the Doctoral Labor Force in 1979 and 1990
[Data Source: National Science Foundation]

In all three alternatives, reductions in both personal and corporate tax rates are expected to stimulate investment, and expenditures for new equipment are expected to grow faster than other types of investment. Sharp increases in defense spending for materials and supplies are anticipated in the 1980's while the non-defense portion of federal purchases is assumed to show no growth.

Expected changes in total employment, professional and technical employment, and science and engineering employment in each of these scenarios is shown in Table 27. Engineers, geologists, engineering and science technicians, computer specialists, economists and psychologists all show higher than average growth in the professional, technical and related occupations group, while life scientists and chemists are expected to grow somewhat below the averages in this group, and the employment of college and university teachers is expected to drop by almost 10%.

• Other projections see significant shortages of trained professionals in some areas of engineering and most areas of computer science. Present faculty shortages in engineering already are extensive. A report prepared for the National Science Foundation[10] found that 10% of all faculty positions in engineering colleges were vacant in fall 1980. Similar faculty shortages exist in computer science (Table 12). Since doctorate production is not rising in either of these fields when foreign graduates on temporary visas are subtracted from the totals, there is little evidence that these shortages will be made up in the near future.

• In a 1981 survey, the American Electronics Association found both current and projected shortages of electrical/electronic engineers and computer scientists.[42] The AEA survey of 1,200 member electronics firms (plus 65 non-member firms) examined 21 job positions within two major technical groups: (1) technical professionals, whose jobs usually require bachelor's, master's or doctorate degrees or comparable experience and (2) paraprofessional/technicians in jobs which usually require a combination of knowledge of basic theory and manual skills received from a community college, a vocational school, or in on-the-job training. Table 28 shows projected growth in these professional and paraprofessional categories in 1981 to 1985, and Figure 21 compares the projected supply and demand of electrical and computer engineers to 1985.

• In contrast to some of the other supply/demand studies, a pilot study of the demand for engineers carried out in 1980 by the Engineering Manpower Commission[44] found that the employers of both electrical and industrial engineers expected to shift from net hiring to net layoff of experienced engineers

Table 27

CIVILIAN EMPLOYMENT IN SELECTED S/E OCCUPATIONS WITH 25,000 WORKERS OR MORE, ACTUAL 1978 AND PROJECTED 1990

Occupation	Employment (in thousands)				Percent Change, 1978-1990		
	1978	1990 Low-Trend	1990 High-Trend I	1990 High-Trend II	Low-Trend	High-Trend I	High-Trend II
Total, All Occupations	97,610	119,590	127,907	121,447	22.52	31.04	24.52
Prof., Tech., & Rel. Workers	15,570	20,038	21,119	20,295	28.70	35.64	30.34
Engineers	1,071	1,504	1,624	1,531	40.41	51.61	42.92
Aero/Astronautic	57	98	104	100	70.35	80.86	74.81
Chemical	53	68	73	70	28.92	37.70	31.80
Civil	149	208	218	211	39.38	45.59	40.97
Electrical	291	441	479	448	51.18	64.41	53.90
Industrial	109	146	159	148	34.03	46.49	36.37
Mechanical	199	274	300	279	37.56	50.67	40.18
Life & Physical Scientists	236	299	316	304	26.44	33.63	28.70
Biologists	42	51	54	53	21.82	28.86	24.98
Chemists	90	113	120	115	24.95	32.19	27.23
Geologists	33	50	53	51	52.08	61.36	52.69
Engr. & Sci. Technicians	1,160	1,577	1,700	1,609	35.97	46.54	38.73
Drafters	293	412	446	419	40.59	52.25	43.20
Electrical & Electronic	319	464	512	478	45.42	60.24	49.79
Industrial Engineering	31	40	44	41	30.37	41.33	32.09
Mechanical Engineering	45	61	67	62	35.96	49.67	38.75
Surveyors	54	73	78	76	35.19	44.73	39.91
Computer Specialists	389	738	793	754	89.83	104.05	93.94
Programmers	204	354	381	361	73.57	86.90	77.22
Systems Analysts	185	384	412	392	107.75	122.97	112.38
Social Scientists	176	243	256	248	38.12	45.51	41.26
Economists	27	41	43	42	54.17	62.93	56.30
Psychologists	78	107	111	109	36.79	42.69	39.31
College & Univ. Teachers	618	557	560	556	-9.78	-9.30	-9.97
College Teachers	454	409	410	408	-10.06	-9.72	-10.28
Graduate Assistants	131	110	110	109	-16.45	-16.13	-16.65

Source: Bureau of Labor Statistics

between 1980 and 1981. Individual engineers, sampled in the same survey, were more optimistic than data from employers would indicate. Overall, 51.6% of the individual engineers saw employment trends as rising.

Employers responding to the survey reported 6% growth in their engineering employment from May of 1979 to May of 1980, and estimated growth for the next twelve months at 6.1%. This overall growth was generally expected to be balanced between college graduates and experienced hires.

Although only 0.8% of the engineers in the survey reported themselves as unemployed and seeking work, 12% to 13% of the workforce reported that they were looking for other employment including some of the 1.6% who were employed part time. The short range demand for engineers by the companies participating in this survey is shown by branch of engineering in Table 29.

• Some studies of demand take in the entire range of scientists and engineers and of potential employers.[34, 41 & 44] Others examine demand within a particular employment sector and for only a few fields.[42] Still others examine demand for a special activity. One such is a recent report from Oakridge Associated Universities on manpower supply and demand for magnetic fusion energy between 1981 and 2000.[48] The Magnetic Fusion Energy Act of 1980 set goals and objectives for the development of magnetic fusion energy technology during the last decades of the century. This report examines manpower requirements for that program. Actual employment in 1981 in magnetic fusion energy and projected employment for 1990 and 2000 are shown by degree level and field in Table 30. Even when considered in relation to competing demands for the same science and engineering manpower, this study concludes that despite increasing demands for B. S. engineers, the increase in new entrants is also expected to be

Table 28

PROJECTED GROWTH AS A PERCENTAGE OF 1980 EMPLOYMENT, 1981-85

(U. S.: AEA Data Only)

	% Growth
Technical Professional Categories:	
Electronic/Electrical Engineers	78%
Mechanical Engineers	70
Mfg/Industrial Engineers	81
Electronic Engineer Technologists	113
Computer Softward Engineers	110
Analyst/Programmers	130
Other Computer Professionals	129
Other Technical Professionals	38
Total All Technical Professionals	76
Paraprofessional Technician Categories:	
Applications/Programmers	149
Engineering Aides	106
Master/Super Technicians	103
Electronic Technicians	103
Jr. Technicians/Testers	139
Field Service Technicians	118
Micro-Electronic Technicians	144
Laser Technicians	228
Assemblers/Operators	109
Drafters	131
Design Drafters	121
Machinists	65
Other Technical Paraprofessionals	56
Total of All Paraprofessional Technicians	102
TOTAL BOTH PROFESSIONALS AND PARAPROFESSIONALS	88

Source: American Electronics Association.

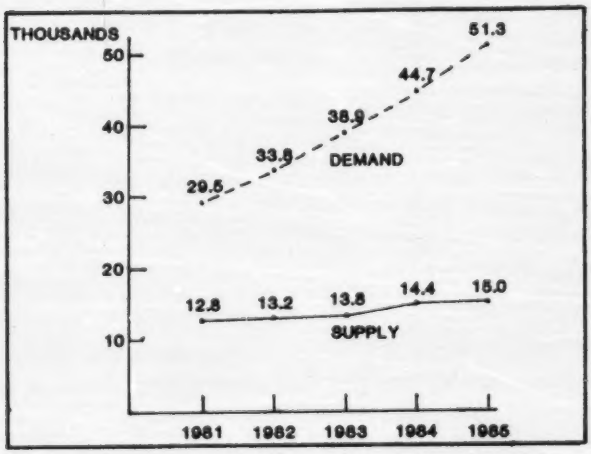

Figure 21. Comparison of Projected Supply and Demand of Electrical and Computer Engineers in U.S. Electronics Industries [Source: American Electronics Association]

strong, except in nuclear engineering. This study assumes that the current tight job market for B. S. engineers will ease by the mid-80's, and that the ratio of new entrants to experienced engineers will increase.

Most of these supply/demand projections indicate that increases in the number of students graduating in most of the science and engineering areas can be expected to fill available job openings created both by growth in employment and replacement of those in the present work force who die, retire, or otherwise leave the profession. In most instances, these projections for graduates indicate a larger supply than can be utilized in science and engineering employment. However, no large scale increase in unemployment for these graduates is anticipated.

Direct employment for all graduates in occupations closely related to their college majors is not necessarily desirable, nor does it represent optimum utilization of education either for the nation or for the individual. If the United States is to maintain a technological lead among other nations of the world, it must have persons involved in the decision making processes of both government and industry who are trained in science and engineering.

Most U. S. industrial management including boards of directors is made up of leaders trained in the law, marketing, accounting and finance rather than in engineering or science. The managers and directors of industry in our principal technological competitors, Japan and West Germany, are predominately trained in engineering.[45] In Japan, about half of senior civil service employees hold engineering degrees (and half of these have post-graduate degrees) permitting government planning by managers educated in technology. Senior civil servants in the U. S., as well as in the Congress, are much more likely to be trained in law.

The economic measures of the Reagan administration are designed to improve capital formation through modification of the tax laws in order to revitalize U. S. industry, introduce modern technologies, improve productivity and increase U. S. competitiveness in the world market. However, any significant revitalization of U. S. industry will require not only the capital formation needed for such revitalization; it will require technologically trained manpower to design, manufacture, install and maintain new machinery and equipment, to carry out the basic research which is the basis for new innovation, and the targeted research which builds on basic research for specialized applications. If the presently perceived need for the scientists and engineers who can perform these tasks is converted to demand by the addition of capital to pay for these services and equipment, the supply of technologically trained specialists may not be sufficient to meet the demand.[46]

Table 29

DEMAND FOR ENGINEERS BY BRANCH OF ENGINEERING

N U M E R I C A L D A T A

Branch of Engineering	No. of Engineers Employed - 5/1/80					No. of Openings as of 5/1/80				
	Total	B.S.	M.S.	Ph.D.	No Degree	Total	B.S.	M.S.	Ph.D.	No Degree
Chemical	6,906	4,953	1,307	646	0	410	308	61	41	0
Civil	9,467	6,984	2,183	295	0	691	549	125	17	0
Electrical	7,420	5,762	1,474	184	0	1,086	1,012	65	9	0
Industrial	911	760	141	10	0	118	113	5	0	0
Mechanical	9,216	7,172	1,711	333	0	928	679	215	34	0
All Other	16,630	7,063	3,201	798	5,568	1,308	724	257	43	284
Total	50,551	32,694	10,022	2,267	5,568	4,541	3,385	728	144	284
	Past 12 Mo. 5/1/79-5/1/80					Forecast 5/1/80-5/1/81				
		Hires		Sep's	NET		Hires		Sep's	NET
	College	Exper-ience	Total			College	Exper-ience	Total		
Chemical	470	162	632	313	319	490	187	677	434	243
Civil	574	506	1,080	635	445	562	527	1,089	658	431
Electrical	522	577	1,099	517	582	622	483	1,105	504	601
Industrial	53	74	127	74	53	56	47	103	71	32
Mechanical	498	348	846	487	359	725	518	1,243	692	551
All Other	755	1,349	2,104	838	1,266	988	1,819	2,807	1,588	1,219
Total	2,872	3,016	5,888	2,864	3,024	3,443	3,581	7,024	3,947	3,077

Source: Engineering Manpower Commission

Whether supply and demand are in balance depends at least in part on the viewpoint of the observer. When individual scientists or engineers, the professional societies for their disciplines, and employers all agree that a shortage or surplus exists, it is probably true. When employers see shortages and individuals and their professional societies see surpluses, supply and demand may well be approximately in balance.

SUMMARY AND CONCLUSIONS

Some trends in scientific and engineering manpower supply and demand seem fairly certain. Except in computer science, the supply of most scientists appears to have caught up with, and generally exceeded the number of job opportunities in science. Nonetheless, actual unemployment continues to be low among scientists, relative to unemployment of other groups with similar amounts of education and training.

For engineers, the picture is not so clear. The number of new engineers graduating at the baccalaureate level has been rising since 1975, and the increase can be expected to continue at least through 1985. A high level of demand has not only fueled that increase, but has utilized so many engineering graduates at the baccalaureate level that graduate enrollments of U.S. students have not climbed commensurately and shortages of Ph.D. engineers have become serious, at least in academic institutions. Programs planned by the administration to bolster defense and revitalize industry in the U.S. will open up new employment opportunities in most fields of engineering throughout the decade. There is disagreement as to whether the supply of engineers will exceed the demand, or whether there will be shortages in at least some engineering disciplines.

The level of funding that will ultimately be established by the Congress and accepted by the President for programs with high technological content, as well as the general levels of funding from both industry and government to support research and development will be major determinants of actual demand. These decisions will be important not only in setting the total numbers of scientists and engineers to be employed, but also in determining the relative mix of scientists and engineers that will be desired. The inability to forecast what these governmental decisions will be is a major reason why dependable forecasts of supply and demand are not readily available. Neither is it possible to predict the unexpected discovery or happening that will change the direction or scope of these efforts.

Table 30

PROJECTED EMPLOYMENT IN DOE-FUNDED MAGNETIC-FUSION ENERGY 1981, 1990 AND 2000 (In Full-Time-Equivalent Person-Years)

	1981		1990		2000	
	BS/MS	Ph.D.	BS/MS	Ph.D.	BS/MS	Ph.D.
Engineers						
Civil	43	1	23	25	18	8
Electrical/Electronic	373	54	502	108	447	133
Industrial	18	6	29	14	29	11
Nuclear	55	53	103	155	115	160
Mechanical*	401	45	720	182	734	142
Engineering Physics	19	14	49	50	64	100
Material Science †	30	57	50	177	48	145
Other	32	19	22	39	12	12
Subtotal	971	249	1,498	750	1,467	711
Scientists						
Physicists						
Plasma	50	479	43	645	24	533
Solid State	0	30	0	51	0	61
Atomic & Molecular	0	27	0	30	0	0
Other	7	13	5	6	3	0
Chemists	19	12	15	34	13	22
Mathematicians	15	12	25	30	22	18
Computer Scientists	74	12	136	27	154	19
Other/ Unspecified	29	0	33	0	31	8
Subtotal	1,165	834	1,755	1,573	1,714	1,372
Other Professionals	116	5	203	14	131	8
Total	1,281	839	1,958	1,587	1,845	1,380

* Includes engineering mechanics.

† Includes metallurgy, material science and ceramics.

Source: Oak Ridge Associated Universities

Increasing or decreasing the supply of trained scientists and engineers requires a lead time of four to eight years. Thus, changes in supply will always lag behind changes in demand. There are now and will continue to be for the foreseeable future some imbalances in supply and demand among scientists and engineers. However, when more persons are trained in these disciplines than are needed for direct employment in them, more technologically trained persons are available for other activities which will benefit from their inclusion. The universities that train scientists and engineers could assist many of their students who will move into nontraditional activities by providing or even requiring some vocational preparation beyond the narrow confines of the academic discipline. Individual students, if aware of the likelihood of employment outside the discipline and of some of the nontraditional careers that have been undertaken by graduates in the seventies may take it upon themselves to acquire additional education or training that would be useful outside of their field.

Only if unemployment among scientists and engineers equals or exceeds the unemployment rate of all persons with similar amounts of education can we assume that supply/demand imbalances require immediate action for reasons of large oversupply.

On the other hand, if shortages of trained manpower in any area become acute enough to curtail or delay vital programs, this will indicate a serious lack of foresight among planners, or a failure to supply known information about the job market to those individuals, universities, and employers who need the best available information in order to make informed decisions and plans.

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